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Mechanical Drawing

A Treatise on Technical Drawing as Expressed through the Medium of the Graphic Language

BY

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PREFACE.

A course in mechanical drawing should be so designed as to awaken the creative faculty of design latent in every student and to so train his mechanical execution that he may correctly express his thoughts through the medium of the graphic language. The power to form a mental image of any proposed design and to represent the object on paper by the necessary views or, conversely, to mentally visualize an object by an examination of the views representing it, is essential to every successful engineer. The training of this technical imagination of the student should receive careful attention throughout any well planned course in Mechanical Drawing. The student should be brought to understand that Mechanical Drawing, so called, is in reality a graphic language with its own alphabet, grammar, and idioms which is to be used as a vehicle of graphic expression. The copying of a set of plates, complete in every detail, while affording practice in the use of instruments and illustrating various standards of execution, is otherwise valueless. A knowledge of the graphic language can no more be gained in this way, than one could become familiar with any other foreign language by merely copying page after page of printed text.

No language can be properly written until the grammar is mastered, nor should working drawings be attempted until orthographic projection, the grammar of the graphic language, has been carefully studied. In the treatment of orthographic projection it would seem obvious that concrete objects, such as solids of various forms, should be first considered before dealing with the more abstruse points and lines. The truth of this statement has been unquestionably proven by the experience of many teachers.

In the appendix at the rear of this book is a suggested course in Mechanical Drawing including twenty-two plates The purpose of the earlier plates is to familiarize the student with the uses of the various instruments and to train his mechanical ex-

ecution. Yet even in these elementary plates an increasing amount of original planning is left to the student subject to the supervision of an instructor. As the plates progress a greater demand is made upon the power of visualizing objects of three dimensions. Those plates which demand a knowledge of orthographic projection are so arranged as to permit the instructor to assign problems of differing data to students working at adjacent tables.

One hour a week may well be spent in class room recitations or lectures. If desired, free hand sketches of assigned models may be made by the student as home work and presented at the recitation period for examination and discussion.

The drawing plates of this text should be completed in a college year in which two two-hour periods per week—or an equivalent amount of time—are devoted to drawing. The theory may be cared for in one one-hour recitation per week throughout the year. The Lettering plates outlined in Chapter III should be completed in twenty one-hour periods.

Grateful appreciation is due to Mr. M. Berry Doub, Instructor in Graphics, Lafayette College, for valuable aid in connection with the preparation of this text, and to Messrs. Kielman '14, Reside '14, and Ellis '15, students in Lafayette College, for their assistance in preparing the illustrations.

The following firms have been most courteous in supplying desired cuts for illustrations: F. Weber and Co., Philadelphia; Keuffel & Esser, New York; Dietzgen & Co., Chicago; Kolesch and Co., New York; and The Technical Supply Co., of Scranton, Pa.

Easton, Pa., O. M. G.
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CHAPTER I.

Instruments and their Use.

1. List of Equipment.—Each man must be provided with the following list of equipment, all articles of which are essential. This outfit is sufficiently complete for the beginner, but as the student gains in experience he will feel the need of useful tools not mentioned in this list. Such further tools or instruments should be procured as experience indicates and finances permit. Any manufacturer is glad to send his catalog upon request, from which much valuable information may be obtained both as to the care and construction of the instruments already purchased and suggestions as to other instruments and devices valuable to the draftsman.

1. Set of drawing instruments of any standard make. The set should contain the following instruments:
   Hairspring Compass, 5½″, with pen and pencil attachments and lengthening bar.
   Hairspring Divider, 5″.
   Bow Pen, 3¼″.
   Bow Divider, 3¼″.
   Ruling Pen, 5½″, with cleaning device.
   Ruling Pen, 4½″, with cleaning device.
2. Drawing Board, 20″ x 28″.
3. T square, 30″, with transparent edge.
4. Triangular boxwood scale, Architect's, or three flat scales.
5. Triangular boxwood scale, Engineer's, or three flat scales.
6. 30°-60° celluloid triangle, 10″.
7. 45° celluloid triangle, 8″.
8. Irregular curve, celluloid.
9. One bottle black, waterproof, India ink.
10. Emery pencil pointer, or file.
11. Ruby pencil eraser.
12. Ink eraser.
13. Sponge rubber, or cube of Artgum.
14. One dozen small thumb tacks.

15. Pen holder, three pens Gillott No. 303, and three pens Gillott No. 404.
16. Two 6H pencils, and one 3H.
17. Medium sized sponge.
18. Small glass bowl.
19. One sheet of Whatman's cold pressed paper, 19″ x 27″.
20. One 3 oz. bottle of white paste.

Assuming the cost of the instruments given in item 1 to be $10.00 (which should be regarded as a minimum), the cost of the foregoing equipment is about $18.00.

The purpose and use of the various supplies enumerated in Article 1 will now be discussed.

2. Instruments.—No more serious mistake could be made than to imagine that a cheap set of instruments is good enough with which to learn to draw, and that a better set may be purchased after proficiency has been attained. The cheaper grades of instruments begin to show signs of wear in a relatively short time. The compasses gradually lose their alignment, the nibs of the pens wear unevenly, pivots become loose and screw threads worn. Instruments in this condition are a source of annoyance and error, and with them even the most experienced draftsman would find it difficult to do creditable work. On the other hand the life of good instruments is practically unlimited if they are used with thoughtful care, and are a constant pleasure to the draftsman. It is then, advisable for those men who intend to make any branch of engineering their life work to purchase as fine instruments as possible. If the state of one's finances prohibits the purchase of a complete set of the finest grade of instruments, it might be well to purchase individually as many instruments as possible at the time, and add to the collection as circumstances permit. Eventually such a buyer would be the possessor of a set of instruments of which he might well be proud. A soft leather case designed to contain any collection of instruments will be made to order by any manufacturer of drafting supplies. Until such a case is desired, the instruments may be kept in a piece of chamois folded so that no instrument is in contact with another.

Those men who are pursuing mechanical drawing only temporarily may reasonably purchase a less expensive set of instruments. In general, however, a set of instruments as enumerated in item 1, Art. 1, which costs less than $10.00 is expensive at any price.

Nearly all of the well known brands of instruments sold in this country are manufactured abroad, notably in Germany and Switzerland. The foremost American made instruments are those manufactured by Theodore Alteneder & Sons of Philadelphia. These instruments have borne an enviable reputation for more than half a century, and many draftsmen consider them to be without an equal.

The Riefler instruments are favorably known abroad and are used extensively in the United States. These instruments are of unquestioned merit and excellence, and are sold by F. Weber & Co. of Philadelphia. The "Sphinx" instruments, manufactured exclusively for the same firm, are acceptable in every way.

The "Paragon" and "Key Brand" instruments manufactured and sold by Keuffel & Esser of New York are worthy of the highest praise. This firm has been eminently successful in the effort to place the manufacture and sale of drafting supplies in general on an honest and reliable foundation.

Eugene Dietzgen & Co. manufacture and sell the "Gem Union" instruments. These instruments have a large sale and are of excellent design and workmanship.

The "T. S. Co." instruments, manufactured for and sold by the Technical Supply Co. of Scranton, are favorably known.

The "Richter" instruments, manufactured in Germany and sold by various agents in this country, are worthy of the highest praise.

The "Kern" instruments are a leading Swiss brand.

Many other instruments are sold in this country and no criticism of them is intended, but in the opinion of the author the ones here named are the best and most reliable.

3. Large Compass.—The principal material used in the construction of this instrument is German silver in rolled sheet form.

The nibs of the pen attachment are made of properly tempered steel in order to afford the requisite spring.

Possibly the most important part of the compass is the head which forms the joint between the two legs. Unfortunately the amateur is unable to ascertain from inspection whether or not

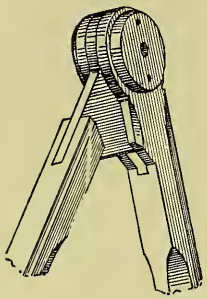


Fig. 1.—Tongue joint.

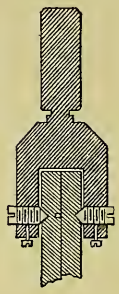


Fig. 2.—Pivot joint.

the head is properly constructed, though a poorly constructed head is sure to make itself annoyingly obtrusive when in use. The surest guide in purchasing is the reputation of the manufacturer and the reliability of the dealer. The tongue joint of former years has now given way to the more desirable pivot

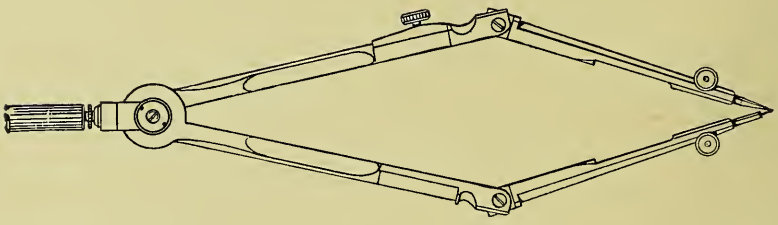


Fig. 3.—Test for alignment.

joint. In the pivot joint each leg terminates in a disc, the two discs being held together in a fork by means of two pivot screws. The fork is provided with a handle for convenience in handling.

All joints and parts should move in the same plane. The test

for this feature is made by bending the legs outward from the head and inward at the knuckle joints, when the points should meet exactly. Every good instrument should stand this test.

The large compass is used for either inking or penciling by means of the two attachments. Circles of about 11″ in diameter may be drawn with the 5½″ compass. If a larger diameter is desired the lengthening bar must be inserted.

In order to avoid making large holes in the paper, use that end of the needle point which has a shoulder. The needle point should be set a little longer than the pen attachment, and kept permanently in this position. When using the pencil attachment adjust the lead to suit the needle point. The lead should be sharpened to a chisel edge about $^{3}/_{64}$″ long. The direction of the edge of the lead should be tangent to the circle drawn; otherwise a line broader than the edge of the lead would result.

To set the compass to any desired radius, place two points on the drawing paper whose distance apart is equal to the given radius. Set the needle point of the compass on one point and spread the other leg until it is approximately over the second point. The exact setting is now made by turning the adjusting screw which controls the hairspring.

The compass should be rotated clockwise, with only enough downward pressure to keep the needle point in place. Do not rotate the compass backward, nor continue the rotation after the circle has been completed. When drawing circles of a large radius, the knuckle joints should be bent so as to bring the two legs perpendicular to the plane of the paper.

If the circle to be drawn is so large as to require the use of the lengthening bar, the leg containing the needle point is steadied with the left hand while the pen or pencil point is rotated with the right hand.

For circles having a radius longer than can be attained by the 5½″ compass and lengthening bar, the beam compass is used. The needle point and the pen (or pencil) point are placed on two separate pieces of metal which are clamped onto a bar of hard wood. These bars may be obtained any length from 24″ to 60″,

so that a circle may be drawn having a diameter of very nearly 120″. A steel bar is frequently used instead of wood. A beam compass of this type is shown in Fig. 4.

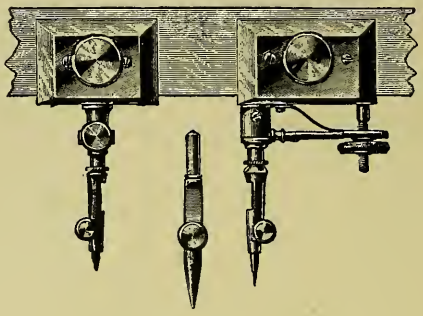


Fig. 4.—Beam compass.

4. Large Divider.—This instrument is similar in general design and construction to the compass except that it has no removable parts. It has a two-fold use, first, to transfer dimensions from one part of a drawing to another, and second, to divide a line into any desired number of equal parts when the divisions cannot be readily obtained from the scale.

To transfer a dimension from one part of a drawing to another, set one leg on an end of the dimension to be transferred and spread the legs until the other divider point is approximately over the other end of the dimension. The exact position of the second divider leg may be obtained by means of the set screw controlling the hairspring attachment. The distance between the points of the divider legs being equal to the given dimension, this distance can be laid off on any desired line. Of course the same

Fig. 5.—Hairspring divider.

result could be obtained by scaling the length of the given dimension, and laying off the same distance by scale on any other desired line. The second method is, however, somewhat more

laborious with the possibility of an error through misreading the scale.

To divide a line into a certain number of equal parts, let it be desired to divide a line which is about 7″ long into five equal parts. Judging solely by the eye, set the divider points a little more than one inch apart and step this distance along the line. Suppose that at the last step one leg extends a small amount beyond the end of the line. Keep the other leg fixed, and by means of the hairspring draw the legs together an amount equal to one-fifth the excess. The line should now be re-stepped and the process continued until the desired result is exactly attained. In stepping off divisions with the dividers, the instrument should be rotated in opposite directions at every other step, as though describing a series of semi-circles alternately on opposite sides of the given line.

Great care should be taken to avoid pricking holes which are needlessly heavy and unsightly. The final points of division should be extremely small, yet easily visible. If it is desired to save these points for future reference, a light free-hand circle should be drawn around each.

5. Bow Pen and Bow Pencil.—The bow instruments, including

Fig. 6.—Bow pen.

pen, pencil, and divider, are made entirely of steel. The legs should have a firm outward spring, and are connected by a

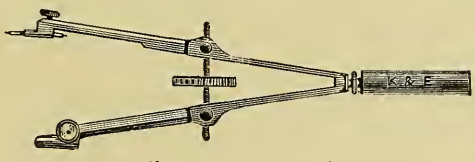


Fig. 7.—Bow pencil.

threaded bar. The distance between the legs is regulated by a thumbnut placed on the threaded bar. The thumbnut may be

placed on the outside of one leg, the legs being held apart, solely by their intrinsic spring. Or the thumbnut may be placed between the two legs, the connecting bar having a right hand thread at one end and a left hand thread at the other end, and engaging the legs in swiveling sockets. The advantage of this type is that the legs are held rigidly in position without depending on the spring. Since the two threads engage simultaneously the motion is double that of a single thread, and the legs can be set with only one-half the number of turns of the thumbnut, which is an added advantage.

Due to the more rigid construction of the bow instruments, circles of small radii can be more accurately drawn than would be possible with the large compass. Moreover the radius is fixed beyond chance of a change due to an inadvertent pressure on the legs. This feature is particularly desirable when drawing a number of circles of the same radii.

The lead of the bow pencil should be brought to a chisel edge having a length of about $^1/_{32}$″, which is nearer a point than in the case of the large compass.

The needle point should project slightly below the pen or pencil point. The proper length is such that in drawing a circle there is no tendency to lift the needle point from the paper, nor the need to unduly force it into the paper in order to keep the moving point in contact with the paper.

The radius may be rapidly changed and the serviceable life of the screw threads be appreciably prolonged, by pressing the legs together with one hand, while turning the adjusting screw with the fingers of the other hand.

Circles having a maximum diameter of 3¼″ and a minimum

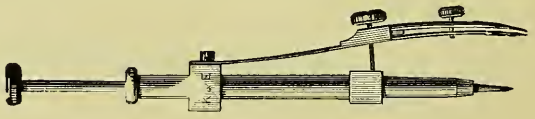


Fig. 8.—Drop pen.

diameter of about ⅛″ can be drawn with a 3¼″ bow instrument. The "drop pen" or "rivet pen" is a more convenient instrument

for drawing circles of very small radius than is the bow pen. If many such circles are to be drawn, such as rivet and bolt holes in structural and machine drawing, and transit stations in topographical mapping, this instrument should be included in the equipment of the draftsman.

6. Bow Divider.—The method of use of this instrument is the same as for the large divider. It is particularly convenient if many divisions are to be made, or if it is desired to keep a certain spacing for some time. The setting cannot be changed without

Fig. 9.—Bow divider.

intentionally turning the adjusting screw, which precludes the possibility of error due to an accidental pressure on the legs while the instrument is not in use.

7. Ruling Pen.—The ruling pen consists of two nibs made of properly tempered steel, fastened to a wood or aluminum handle. The nibs should be fairly sharp, slightly rounded, and of equal length and shape. The two nibs are held together by means of a small screw, one nib having a strong outward spring which keeps that nib flush against the head of the screw. The distance between the nibs is controlled by the screw, thus rendering it possible to draw any desired width (frequently called "weight") of line.

The pen is filled by means of the quill attached to the stopper of the ink bottle. Do not put too much ink in the pen at one time. The ink should not extend upward from the points of the nibs more than ¼". The danger of overloading the pen is that the ink is apt to be shaken from between the nibs, causing blots. After filling the pen see that no ink remains on the outside of the nibs. In ruling a line hold the pen almost vertical, but with a slight lean to the right. That nib which touches the screw head should be on the far side from the edge of the T

square or triangle. All lines should be drawn from left to right with a free arm movement, making sure that both nibs are in constant contact with the paper. If either nib fails to touch the

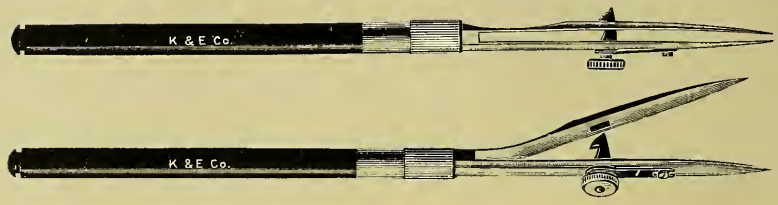


Fig. 10.—Ruling pen with cleaning device.

paper, by reason of the pen leaning toward or away from the draftsman, that edge of the line will be ragged.

India ink dries rapidly, leaving a slight deposit which if permitted to remain between the nibs will cause an uneven flow of ink and a consequent variation in the width of the line. Hence the nibs should be frequently cleaned by drawing between them a soft cloth kept for that purpose. Thoroughly clean the pen

Fig. 11.—Ruling pen with cleaning device.

before putting it away after the day's work. Most beginners are apt to excuse poor work on the ground of a fault in the pen. It is far more frequently the case that the pen is not kept sufficiently clean to allow a uniform flow of the ink. Remember that the ink cannot possibly flow if the nibs are screwed together until they are in contact.

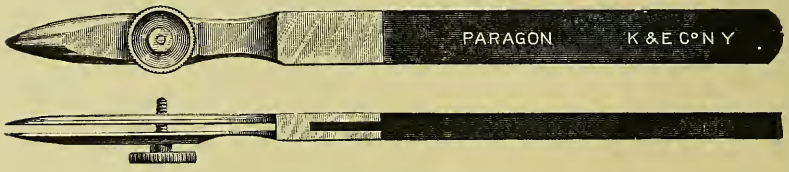


Fig. 12.—Detail pen.

In order to clean the dried ink from between the nibs of the pen it is necessary to open the nibs to their full extent. Care

must then be taken to carefully reset the nibs to their original spacing so that lines drawn before and after cleaning will show no variation in width. This need has given rise to several forms of "cleaning devices," by which the nibs are automatically returned to their original positions. Two different forms of this device are illustrated in Figs. 10 and 11.

A double pen is frequently useful for ruling two parallel lines. Or a single very broad line can be obtained by filling the space

Fig. 13.—Double ruling pen.

between the two pairs of nibs with ink as well as the space between each pair of nibs.

A curve pen set into the handle with a swivel joint is useful in drawing curves, contour lines in mapping, etc.

Fig. 14—Curve pen with swivel joint.

The Payzant pen for free hand single stroke lettering is a most useful device.

Fig. 15.—Payzant freehand lettering pen.

8. Drawing Board.—The drawing board should be made of narrow strips of soft pine about one inch thick. The strips should be held firmly together by hardwood ledges secured by screws in oval slots to allow for contraction and expansion. A series of grooves equal in depth to half the thickness of the board should be sunk on the under side of the board to prevent warping. A hardwood straight edge glued to each end of the board is desirable though not essential. The under side of a well made board is illustrated in Fig. 16.

One of the short edges is made perfectly smooth and even and is called the "working edge." This working edge is placed to the left to receive the head of the T square. The evenness of the working edge is best tested by applying a steel straight

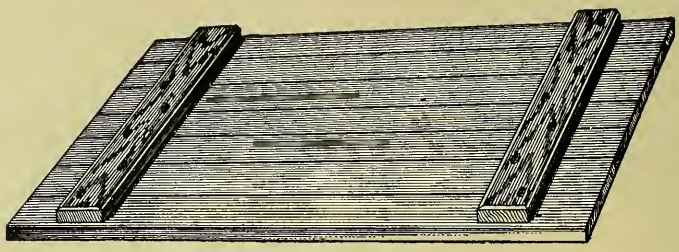


Fig. 16.—Drawing board.

edge. Or it may be tested as follows: hold the head of the T square firmly against the working edge and draw a pencil line through the center of the paper. Using several points on this line as centers, draw arcs of equal radii on each side of the line. If the T square be moved along the working edge and can be brought tangent to the arcs just drawn, the working edge is perfectly straight. This test assumes that the T square itself is accurate.

It is sometimes convenient to rule lines parallel to the working edge by placing the head of the T square against the edge of the board nearest the body. This is permissible only when the two edges are known to join at an angle of exactly 90°.

The upper and right hand edges are never used under any circumstances.

9. T Square.—The T square consists of a long, light blade rigidly attached at right angles to a head which is about double the thickness of the blade. The most accurate and durable T squares are made of steel, but the great majority in ordinary use are made from woods such as cherry, maple, pear, or ash. The two edges of the blade should consist of some transparent material such as celluloid. The transparent edge renders it possible to observe the work immediately adjacent to the line being drawn, which is very helpful.

An adjustable T square is one which permits the angle between

Fig. 17.—T Squares with celluoid edges.

Fig. 18.—T Square with micrometer adjustable head.

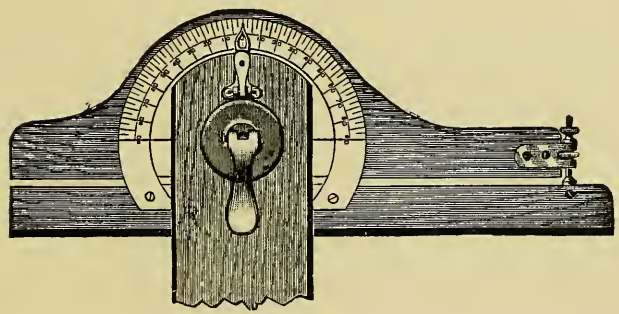


Fig. 19.—T Square with micrometer adjusted protractor head.

the head and the blade to be regulated as desired. This type of T square is convenient though not essential.

In Fig. 20 is shown a T square holder which, when attached to the end of the blade, holds the T square from slipping by pressing against the drawing board. This device is particularly useful on a long blade.

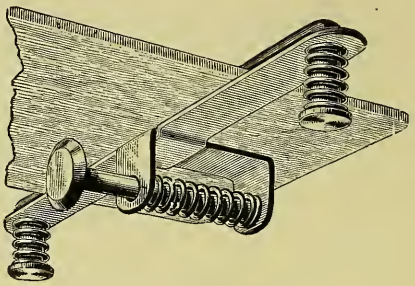


Fig. 20.—T Square holder.

To use the T square, press the head firmly against the working edge of the board with the left hand. Slide the left hand along the blade, to hold it firmly in position while drawing the line with the right hand. Move the T square up and down the board by means of the head. Use only the upper edge of the blade.

To test the blade for straightness: draw a line the full length of the blade. Turn the T square, end for end, and if it can be made to coincide with the line already drawn the ruling edge is perfectly straight. The same ruling edge must be used, of course, in each position of the T square.

10. Scales.—The two most common materials from which scales are made are steel and boxwood. The main advantages of the steel scale are its durability and the permanency of its deep cut graduations. On the other hand the divisions are difficult to read and prove a constant strain on the eyes. For general use the boxwood scale is to be preferred, the edges preferably being covered with some white material on which the graduations are stamped in black.

Scales are divided, as regards shape, into two main divisions, flat and triangular. The triangular shape has the advantage of containing on one scale all of the eleven sets of graduations in common use. Its disadvantage is the danger of mistaking the

proper scale. A flat scale similar to the one shown in Fig. 23 and containing four sets of graduations is the most desirable form. However, three such scales are needed to contain all of the desired graduations.

In general the representation on paper of an object is necessarily smaller than the actual size of the object represented. The purpose of the scale is to facilitate this required reduction. Suppose that it is desired to draw an object one-twelfth of its actual size. Then for every twelve inches of the object, one inch must be laid off on the drawing; the equivalent expression of which is to say that one inch on the drawing is equal to twelve

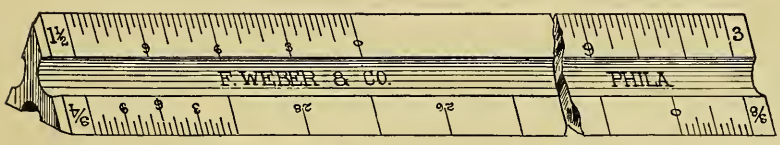


Fig. 21.—Triangular boxwood scale, architects'.

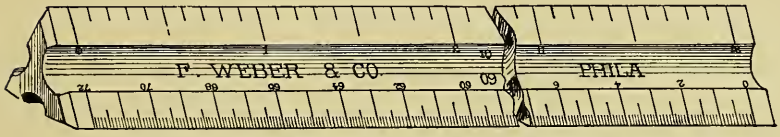


Fig. 22.—Triangular boxwood scale, engineers'.

inches of the object. The scale to be used is, then, one inch equals one foot. If on any straight edge points be set one inch apart, the included spaces will represent one foot. If one space be now divided into twelve parts, each division will represent one inch; each division may be sub-divided into four parts, each sub-division representing one quarter inch. With a scale so divided, distances may be laid off such that the resultant drawing will be one-twelfth the actual size of the object. The evident advantage of the scale is that it obviates the necessity of any mental division on the part of the draftsman. In Fig. 23 the distances 1′-0″ and 10′-10½″ are laid off to a 1″ scale. The distances 2′-0″ and 20′-7″ are laid off to a ½″ scale.

The triangular architect's scale contains the following graduations which are the ones most frequently used:

$12'' = 1'\text{-}0''$	(Full size)
$3'' = 1'\text{-}0''$	(One quarter size)
$1\frac{1}{2}'' = 1'\text{-}0''$	(One eighth size)
$1'' = 1'\text{-}0''$	(One twelfth size)
$\frac{3}{4}'' = 1'\text{-}0''$	(One sixteenth size)
$\frac{1}{2}'' = 1'\text{-}0''$	(One twenty-fourth size)
$\frac{3}{8}'' = 1'\text{-}0''$	(One thirty-second size)
$\frac{1}{4}'' = 1'\text{-}0''$	(One forty-eighth size)
$\frac{3}{16}'' = 1'\text{-}0''$	(One sixty-fourth size)
$\frac{1}{8}'' = 1'\text{-}0''$	(One ninety-sixth size)
$\frac{3}{32}'' = 1'\text{-}0''$	(One one hundred twenty-eighth size)

A half size scale may be employed by mentally dividing all actual dimensions by two, and then using the full size scale.

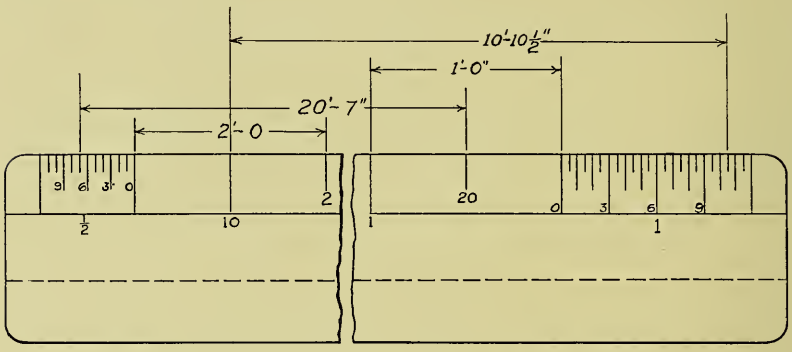


Fig. 23. — The use of the scale in laying off dimensions.

The triangular engineer's scale is divided into 10ths, 20ths, 30ths, 40ths, 50ths, and 60ths of an inch. The engineer's scale is used for plotting all work the measurements for which were taken in the decimal system. It is particularly valuable to the civil engineer in the plotting of maps and surveys.

Transfer distances directly from the scale to the paper, marking the points with a finely pointed lead pencil. Do not set the divider or compass legs against the scale graduations and attempt

to transfer distances by this means. The method is inaccurate and has a disastrous effect on the graduations.

In laying off a number of equal distances carry the summation of distances on the scale. Thus if it be required to lay off 24 divisions of $\frac{3}{8}''$ each, set the zero of the scale at the starting point and, holding the scale fixed, successively lay off $\frac{3}{8}''$, $\frac{3}{4}''$, $1\frac{1}{8}''$, $1\frac{1}{2}''$, etc. The last point set should fall at the 9″ mark, which furnishes a valuable check on the work.

11. Triangles.—Triangles are made of wood, rubber, steel, and celluloid. Though the steel triangles are more lastingly accurate than those made from any other material, they are not popular due to their weight and opaqueness. The celluloid triangles are fairly accurate, light, easily handled, transparent, and for general work are to be preferred to those of any other material.

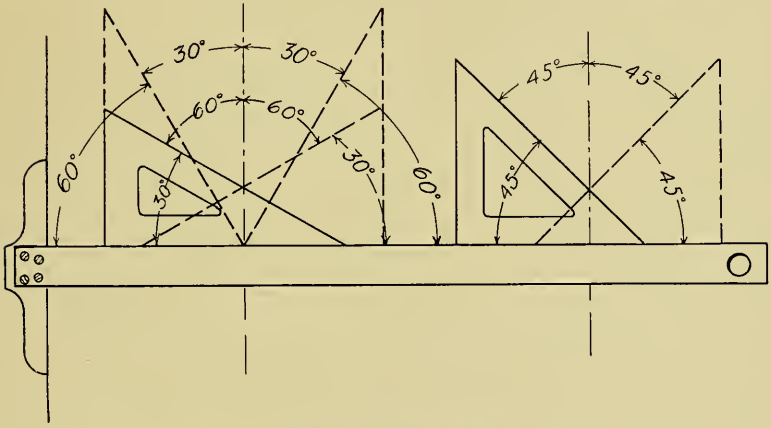


Fig. 24.—Use of triangles—to obtain angles of 30°, 45° and 60°.

It is advantageous to have several sizes of both the 30°-60° and 45° triangles, as it is not convenient to draw large figures with small triangles or vice versa.

As the speed of the draftsman is largely dependent upon his facility in the use of triangles in connection with the T square, the beginner should at once familiarize himself with their various uses, singly and in combination.

Lines drawn parallel to the blade of the T square are known as horizontal lines. Vertical lines are perpendicular to horizontal lines.

By placing the triangles firmly against the T square blade, vertical lines and lines making angles of 30°, 45°, and 60° with the horizontal (or vertical) may be drawn. Lines making angles of 15° and 75° with either the horizontal or vertical may be

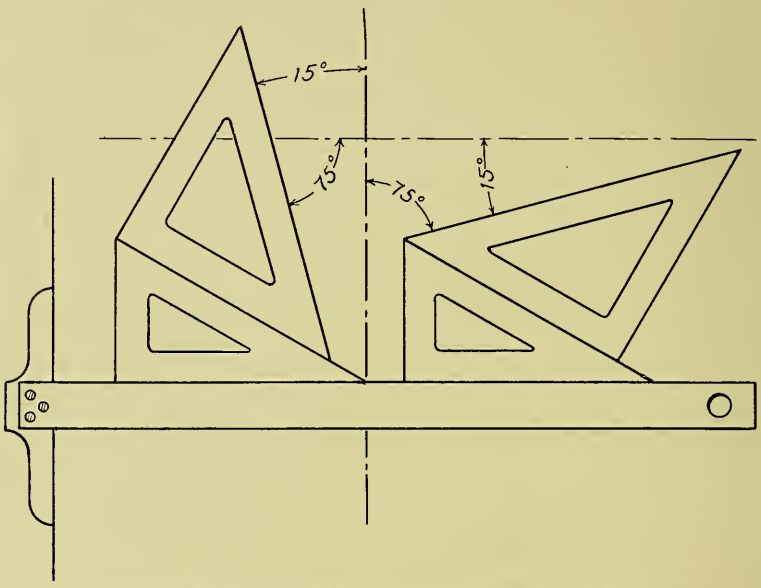


Fig. 25.—Use of triangles—to obtain angles of 15° and 75°.

drawn by combinations of the two triangles as shown in Fig. 25. The student should draw through a point a series of radiating lines 15° apart from 0° to 360° by means of the T square and triangle only.

If it be desired to draw a series of parallel lines which are neither horizontal or vertical, place the triangles in conjunction and slide one along the other which is held fixed by the left hand.

To test the right angle of either triangle, hold the triangle against the T square with the vertical edge at the right and draw

a fine vertical line. Reverse the triangle so that the vertical edge is at the left. If the vertical edge now coincides with the line already drawn the angle is 90°. If the edge and line do not coincide they will form an angle one-half of which represents the error in the 90° angle of the triangle. If the vertex of the

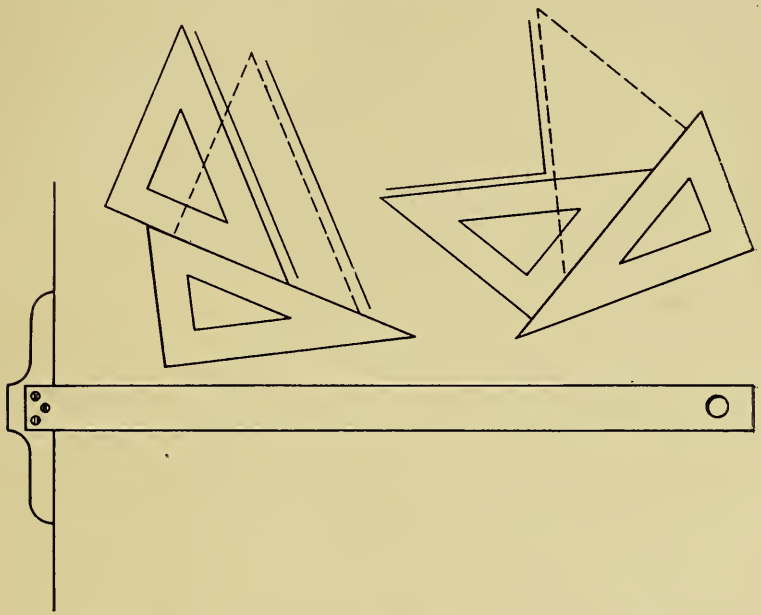


Fig. 26.—Use of triangles—to draw parallel and perpendicular lines.

angle is at the top, the angle of the triangle is greater than 90°; if the vertex is at the bottom the angle of the triangle is less than 90°.

To test the 45° triangle, hold the triangle against the T square and draw a line along the hypotenuse. Interchange the positions of the two acute angles. If the hypotenuse now coincides with the line already drawn, the angle of the triangle is exactly 45°. If they do not coincide the amount and direction of the error is determined as in the preceding paragraph. This test is based on the assumption that the 90° angle has already been tested and found to be correct.

To test the 60° triangle; by means of a protractor or geometrical construction, draw a line making an angle of 60° with the blade of the T square. Place the short edge of the triangle against the T square, and if the hypotenuse then coincides with the line already drawn, the 60° angle of the triangle is correct. The 90° angle should have been previously tested. If the 60° and 90° angles are correct the remaining angle must be exactly 30°.

The side of a triangle which has been proven inaccurate by any of the foregoing methods may be materially improved by a judicious application of sand paper.

12. Irregular Curves are constructed of rubber, wood, and celluloid, the latter material being preferable. It is frequently desir-

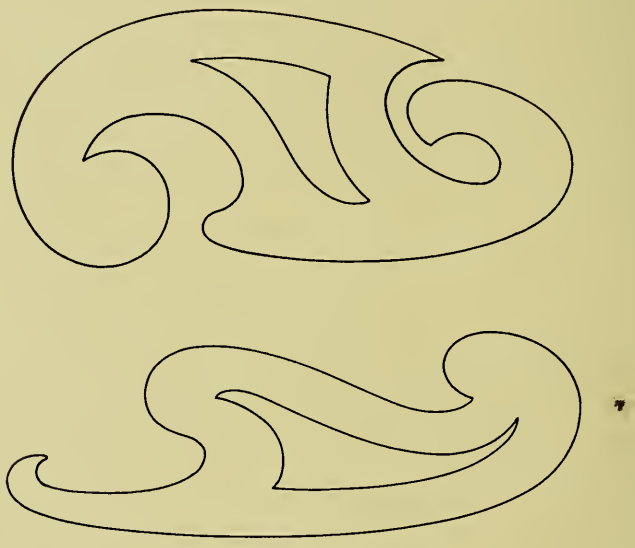


Fig. 27.—Irregular curves.

able to make pencil marks on the surface of the curve, hence many draftsmen roughen the surface of the celluloid with sand paper. The curves are made in a variety of shapes and sizes, but for general use the curves of long radii are most desirable.

A varied collection of irregular curves is a valuable part of a draftsman's equipment.

In using an irregular curve do not ink the curved line to the full extent of the distance that it apparently matches the irregular curve. The importance of this statement can hardly be sufficiently emphasized. Let it be required to draw a curved line through points *a, b, c, d, e, f, g, h, i, j, k,* etc. If the curve can be fitted from *a* to *f* draw the line only as far as *e*. Now fit the curve from *d* as far as possible, say to *i,* and draw the line from *e* to *h*. Fit the curve from *g* as far as possible, say to *k,* and draw the curve *h* to *j*. Proceed in this manner until the curve is complete. By this method there are no visible and unsightly joints in the curved line.

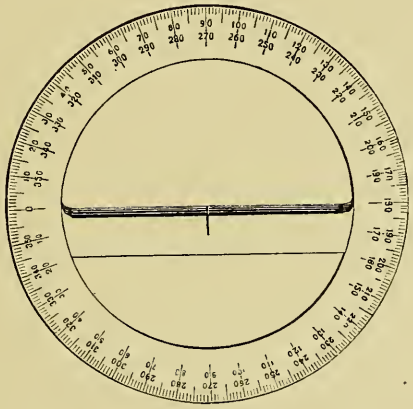


Fig. 28.—Protractor, particularly adapted to mapping.

In drawing a curved line which is symmetrical in respect to a given axis, mark with a pencil on the surface of the irregular curve the portions used in drawing one-half of the curve, and then use the same portions in drawing the other half of the curve. By this means the symmetry of the curve is preserved. In order to make sure that the two symmetrical halves join one another in a smooth curve, it is frequently advisable to stop each

half just short of the axis and use a separate portion of the irregular curve for the connection.

13. Protractor.—A protractor is a device by means of which angles of any desired number of degrees may be laid off. It is a necessity in nearly all forms of topographical mapping and is frequently useful in machine drawing. A simple form of pro-

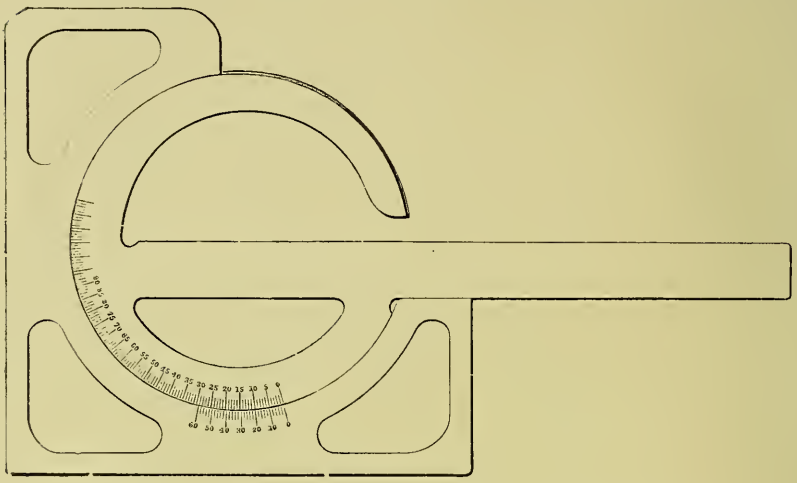


Fig. 29.—Protractor, particularly adapted to machine drawing.

tractor intended for general use and mapping is shown in Fig. 28. The protractor shown in Fig. 29 is made of sheet steel with an 8½″ blade. The vernier reads to five minutes. This form is particularly adapted to the requirements of machine drawing.

14. Pencils.—There are many good brands of pencils on the market and an equal number of poor ones. Among the former may be mentioned the excellent "Koh-i-Noor" pencils manufactured by L. & C. Hardmuth and sold by all dealers. The "Apollo" pencils manufactured by F. Weber & Co., the "Hyperion" pencils of Eugene Dietzgen, Keuffel & Esser's "Paragon" pencils, and the "Swan" pencils sold by the Technical Supply Co. of Scranton are to be highly recommended.

The standard gradation of pencils according to the degree of hardness of the lead is commonly accepted as follows: 6B, 5B,

4B, 3B, 2B, B, HB, F, H, 2H, 3H, 4H, 5H, and 6H. According to this notation F and HB are considered medium, the leads growing harder through the H's until 6H is reached and softer through the Bs until 6B is reached. The degree of hardness desired by the draftsman is considerably dependent upon the class of work and the grade of paper employed. In general the 6H pencil is used for line drawing which is to be traced or inked, and the 3H pencil for lettering.

The draftsman should possess two 6H pencils, one of which should be brought to a chisel edge as follows: cut away the wood for about 1¼", exposing about ⅜" of the lead. Flatten the lead and bring to a knife edge by rubbing on an Emery pencil pointer or file. The other 6H pencil is sharpened to a long conical point for the laying off of dimensions.

Some draftsmen prefer to bring one end of the pencil to a chisel point and the other end of the same pencil to a conical point. It is claimed that this method saves time, since it is quicker to turn the same pencil end for end in laying off a dimension, than to lay down one pencil and pick up another. On the other side it may be said that the continued sharpening of a pencil at both ends rapidly decreases its useful length. At best, this is a matter of personal choice and that method should be adopted which is best suited to one's own needs. It is imperative, however, that a 6H conical pointed lead be kept for no other purpose than the laying off of dimensions.

15. Ink.—One of the best inks manufactured for drafting purposes is Higgin's Water-proof India Ink. Other excellent inks are made by F. Weber & Co., Keuffel & Esser and Eugene Dietzgen. Inks are made in many colors, though the practice of using colored inks on drawings is steadily decreasing. The use of colored inks on some forms of mapping is frequently advantageous.

16. Paper.—Drawing paper is made in a variety of styles to meet a variety of needs. In general, the white papers are intended for finished or inked drawings, and the cream or buff papers for pencilled or detail drawings. In the average drafting

room by far the greater number of drawings are made in pencil on the buff or cream detail paper. These drawings are then traced and from the tracing blue prints are obtained; this process will be described later. Many drawings are made, however, directly in ink on white paper. Maps, railroad layouts, or any other drawings which may have to stand hard use, are made in ink on a heavy white paper backed with tough linen. The surface of such a drawing is sometimes protected by a coat of white varnish.

A paper intended to receive ink should be white, of close firm texture, and should neither repel nor unduly absorb liquids. A good paper should stand at least four successive erasures of an ink line.

Two papers which meet these requirements are Whatman's and F. Weber & Co.'s "Fabriano." These papers are made in standard commercial sized sheets, or in 10 to 50 yard rolls, with three styles of finishing the surface, hot pressed (smooth), cold pressed (medium), and rough (course grained). The cold pressed paper is the most serviceable for general use. That side of the paper from which the makers water mark can be read is regarded as the "right" side.

17. **Erasers.**—For the erasure of pencil lines use a Ruby eraser.

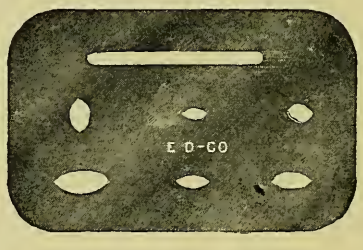


Fig. 29*a*.—Erasing shield.

Ink lines may best be erased by removing only the surface of the line with an ink eraser, completing the erasure with a Ruby eraser. Under no circumstances should any form of "scratcher" or knife blade be used for erasing.

An erasing stencil consisting of a thin piece of metal containing holes of various shapes may be used to protect other lines adjacent to the one being erased.

A soft sponge eraser, or cube of Artgum, is serviceable in giving the drawing a general cleaning without erasing any lines.

18. Miscellaneous.—Thumb tacks are useful for temporarily holding the drawing in place or for holding reference notes or sketches to the board.

If the paper is not to be stretched and the margins pasted down, it should be held in place by one-ounce iron tacks. These tacks can be pushed into the board until their heads are flush with the paper. Such tacks offer no obstacle to the sliding back and forth of T square and triangles as do the thumb tacks.

The pen holder should have a large grip (about ½″ in diameter) tapering off into a slender handle. The best material for the grip is cork or soft unglazed wood. Gillott's No. 303 and No. 404 are excellent pens for medium sized free hand lettering.

A pen wiper should be kept close at hand and frequently used. Chamois or lintless linen are excellent materials for this purpose.

The sponge, glass bowl, and jar of paste are used in making a stretch as described in Art. 19.

CHAPTER II.

General Instructions.

19. To Make a Stretch.—Lay the paper on the drawing board and fold upward about ½″ of each edge. Fill the small glass bowl with water and by means of the sponge thoroughly wet the exposed surface of the paper taking care not to dampen the folded edges. Squeeze all water from the sponge and remove all surplus water from the paper by absorbing it with the sponge. Spread paste on the inner surfaces of the folded margins. Lift the paper from the board and lay the side which has been wet next to the board. Paste the margins to the board working from the center outward and at the same time smoothing as many wrinkles as possible from the paper. The paper should be allowed to dry in a horizontal position, and when dry should present a smooth surface free from wrinkles with edges firmly fastened to the board.

20. Penciling.—The pencils should be sharpened as stated in Art. 14, the 6H being used for the drawing of lines and the 3H for lettering.

In making a line hold the pencil nearly vertical with a slight inclination to the right. The chisel point should touch the paper about $^1/_{32}$″ away from the straight edge. All lines should be drawn from left to right and away from the body, even though to do this necessitates the turning of the drawing board or moving around the drafting table, so that the free and even movement of the arm may not be cramped. The lines should be very fine which is accomplished only by maintaining a sharp edge on the chisel point of the pencil.

The student should always remember that the three essential characteristics of a good draftsman are **speed, accuracy** and **neatness.** The last two go hand in hand and are of more importance than the first.

21. Character of Lines.—For ease in reading a drawing, various kinds of lines are used, each kind expressing to the trained eye a certain fixed meaning. Unfortunately there is no universally

accepted standard, but the alphabet of lines shown in Fig. 30 is commonly accepted by most draftsmen in this country.

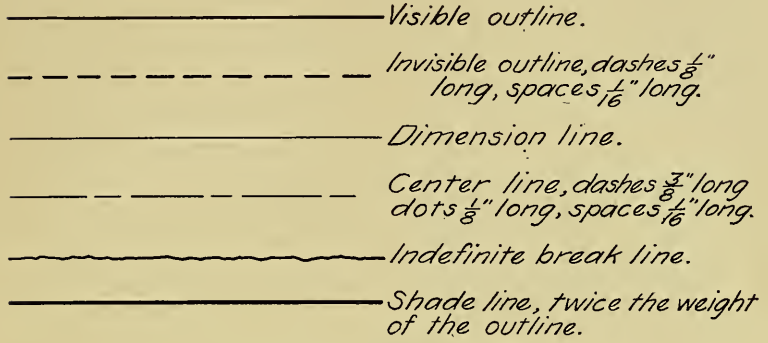

Visible outline.
Invisible outline, dashes ⅛" long, spaces 1/16" long.
Dimension line.
Center line, dashes ⅜" long dots ⅛" long, spaces 1/16" long.
Indefinite break line.
Shade line, twice the weight of the outline.

Fig. 30.—Character of lines.

The dimensions given are to be judged solely by the eye. Practice so trains the judgment of the eye that these distances can be obtained with surprising accuracy. Uniformity in the length and spacing of the dots and dashes should be maintained, however long the line may be. The otherwise pleasing effect of a drawing is easily marred by irregularity in dot and dash lines. The same degree of care, in this regard, is not as essential in pencil work which is to be inked or traced.

On inked drawings all the lines shown in Fig. 30 should be drawn in black ink. A space is left near the center of dimension lines for the insertion of figures. In structural drawing the dimension line is continuous and the figures are placed just above the line. The use of colored inks for dimension and center lines is not desirable as it requires a greater expenditure of time on the part of the draftsman, and good prints cannot be made from tracings on which colored inks were used. Happily the modern practice is to use only black ink on all drawings which are not to be colored for display. An interesting inquiry into modern drafting room practice, conducted by Prof. Reid of the Armour Institute of Technology, shows that only 13 per cent. of one hundred firms questioned use colored inks for dimension and

center lines. The remaining 87 per cent. use the black line as stated above.

22. Inking.—In general a drawing should be complete in pencil before starting the inking. The speed of the inking will be greatly increased if some definite system is followed such as the one here outlined:

1. Ink all circles and circular arcs first, beginning with the smallest.
2. Ink all horizontal dotted lines.
3. Ink all vertical dotted lines.
4. Ink all other dotted lines.
5. Ink all horizontal full lines.
6. Ink all vertical full lines.
7. Ink all other full lines.
8. Ink center and dimension lines.
9. All figures and notes.
10. All cross hatching.
11. Title and border.

In inking horizontal lines, ink those at the top of the drawing first, and work downward; in inking vertical lines, ink those at the left of the drawing first and work to the right.

The tendency of the student is to make all lines too light. The finest line should be heavy enough to stand out clear and bold to the eye. There should be no minute white spaces in the line indicating that the nibs of the pen were set so close together as to render impossible an even flow of ink. It is advisable to rule on scrap paper a standard set of the lines to be used on the drawing. These lines may then be referred to when resetting the pen after cleaning. This is not so essential if the pen contains a device which automatically returns the nibs to their original position after cleaning.

23. Symbolic Cross Hatching.—It is frequently desirable to represent an interior view of an object as though it had been exposed to view by an imaginary cutting plane, that portion of the object between the observer and the cutting plane being regarded as removed. Such a view is called a section, and is

indicated on the drawing by covering the area in question with parallel straight lines, usually making an angle of 45° with the horizontal. These lines are called cross hatching.

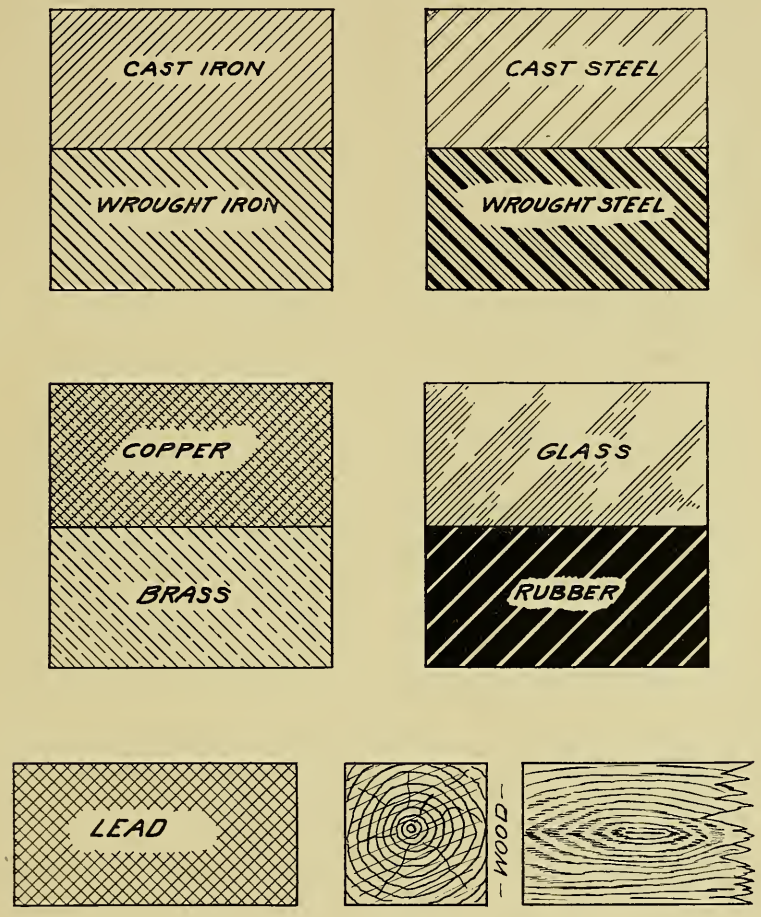


Fig. 31.—Symbolic cross hatching.

By varying the character and spacing of the lines composing the cross hatching various materials may be indicated. There is no universally accepted standard of symbolic cross hatching due,

possibly, to the great number of materials used in engineering construction. It is advisable, therefore, to plainly letter the material in addition to the symbolic cross hatching, the function of the latter being only to indicate that different materials are used in the given design. The conventional symbols shown in Fig. 31 are accepted and used by many draftsmen in this country.

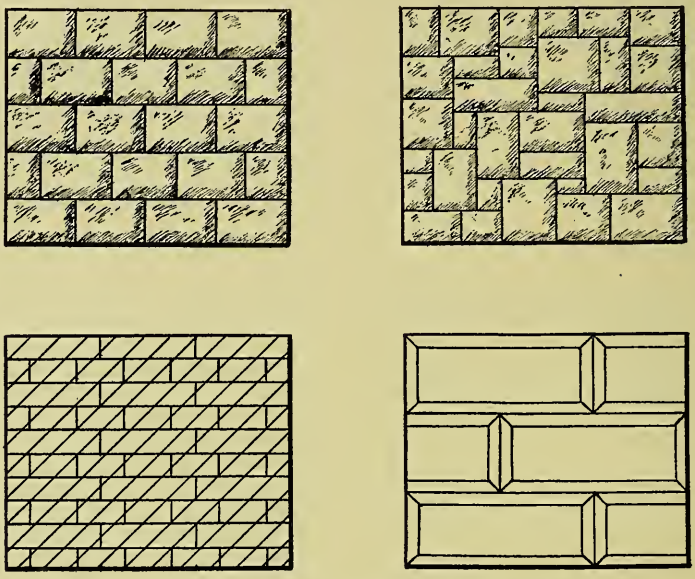


Fig. 31*a*.—Representation of stone and brick masonry.

It is to be noted that different materials in the same section are best contrasted by sloping the cross hatching in opposite directions.

The spaces between the lines of the cross hatching are judged solely by the eye, but care should be taken to maintain uniformity of spacing. It is a helpful guide to glance back at the spacing of the last four or five lines drawn. Various forms of "section liners" are on the market which are merely devices for mechanically regulating the spacing. Unless a great amount of cross hatching is being done their purchase is not to be recommended. A home-made device to accomplish the same purpose is shown

in Fig. 32. It is made of thin wood and is used by slipping the block and holding the triangle, then holding the triangle and slipping the block, etc. One piece of wood will evidently maintain the same spacing and cannot be changed, so that several pieces should be kept on hand for various spacings.

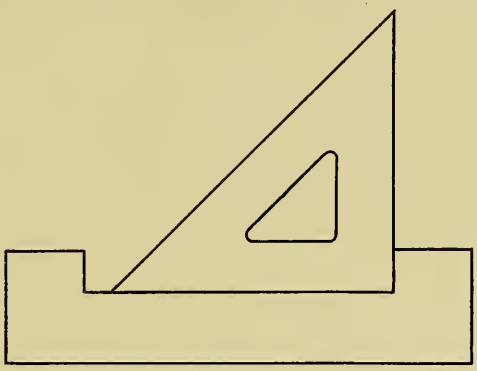


Fig. 32.—Section line device.

The width of the spaces is largely dependent upon the area to be cross hatched and no rule in this connection can be given. The tendency of the student, however, is to place the lines too close together.

24. Tinting.—On large drawings it is frequently more advantageous to distinguish various materials by the use of different colored washes, instead of by cross hatching. Tinting is also largely used in map drawing to clearly indicate the various divisions of the map. Architectural drawings are nearly always tinted, thereby gaining greatly in beauty and realistic effect.

The paper should be of good quality and cold pressed.

The size of the brush should depend somewhat on the area to be tinted, sharp turns and small corners demanding a finer pointed brush than would a large unbroken area. In any case the brush should naturally assume a good point when filled with the wash or plain water.

The wash is prepared by lightly rubbing the moistened brush on a cake of color and then stirring the brush in a small porce-

lain or china dish containing water. The wash had best be too light in color rather than too dark. The tinted area may easily be darkened by applying a second coat of the wash. But if the original wash is too dark, it is an extremely difficult task to lighten the tinted surface.

Before applying the wash the board should be inclined at an angle of approximately 15°, so as to induce a gentle downward flow of the liquid.

Fill the brush with the wash, and starting at the upper portion of the drawing apply the wash from left to right in such a quantity as to form a narrow horizontal puddle of the wash. Draw this surplus color downward, continuing to work from left to right. When the bottom edge is reached, dry the brush by pressing between the thumb and forefinger of the left hand, and use the brush as a sponge to absorb the surplus wash. Any part of the wash which has perchance been drawn outside the bounding lines of the figure, should be permitted to thoroughly dry before removing with a pencil eraser.

A graded tint may be secured by applying at the upper edge of the area the darkest color desired and drawing the wash downward by adding with the brush a gradually increasing quantity of pure water.

Since sediment is apt to form in the bottom of the saucer containing the wash, it is better to touch the brush to the upper portion of the wash, not permitting it to touch the bottom of the dish.

25. Erasing.—Pencil lines should be erased by means of a Ruby or Emerald eraser. The small particles of rubber caused by the erasing should be dusted off with a brush or cloth. The palm of the hand, if clean and dry, may also be used for this purpose.

Ink lines should not be erased until thoroughly dry. India ink seldom penetrates the surface of good drawing papers. The endeavor should be to remove the coating of ink without injuring the surface of the paper. This is best accomplished by disturbing and loosening the coating of ink with an ink eraser,

and finishing the erasure with a pencil eraser. Any form of knife edge or scratcher should be used with the greatest care. The danger of such a tool is that the surface of the paper may be so destroyed as to render it impossible to re-ink over the erasure.

It is frequently desirable to give a drawing, a general cleaning. This may be accomplished by lightly rubbing the drawing with a sponge rubber or piece of Artgum. Pass over the inked lines as lightly as possible as even the softest rubber tends to slightly destroy the intense blackness of the ink which is so desirable.

Many draftsmen satisfactorily clean a drawing by rubbing bread crumbs over its surface with the palm of the hand.

26. Abbreviations.—The following abbreviations are frequently used in many drafting rooms:

Feet or Foot	Ft., ft., or ′.
Inches or Inch	In., in., or ″.
Degrees or Degree	°
Minutes or Minute	′
Seconds or Second	″
Angle	∠
Center to Center	c to c.
Pitch	P.
Diameter	Dia. or D.
Radius	Rad. or R.
Circumference	Circum.
Hexagonal	Hex.
Square	Sq.
Threads	Thds.
Threads per Inch	Thds. per In.
Revolutions per Minute	R. P. M.
Pounds	lbs or ≠

There is far less uniformity of practice as regards the symbolic meaning of colors to represent various materials, than is the case in cross hatching. The following washes are used by some large concerns, but are by no means universal:

Cast Iron	Payne's Grey
Wrought Iron	Russian Blue
Steel	3 parts Russian Blue, 1 part Crimson Lake.
Brass	Gamboge
Copper	4 parts Crimson Lake, 1 part Burnt Sienna
Lead or Babbitt	Light India Ink
Glass	Light Prussian Blue with line shading
Brick	Crimson Lake with section lines

Manufacturers of drafting supplies have on the market various colors labelled "Cast Iron," "Steel," "Wood," etc., which closely approximate in color the material to be represented. Until some standard is authoritatively recommended by the leading engineering societies and generally adopted by draftsmen, all sections should be clearly lettered whether cross hatched or tinted.

CHAPTER III.

Lettering.

27. Purpose.—It is hardly possible to convey on a drawing the required information by means of the graphic language of lines alone. Such data as the figures representing lengths and sizes, explanatory notes, statements as to kind of material, finish, number of pieces desired, title, etc., must be lettered. If the lettering is to be serviceable it must be neat and legible, and of a style that permits rapid execution.

28. Style.—The style of lettering adopted for working drawings should possess these three important characteristics, **beauty, legibility,** and **ease of execution.** If any one of these features be lacking the quality of the other two is necessarily depreciated.

Beauty to the trained, technical eye does not mean ornate letters with fancy scrolls and appendages, but rather letters that are appropriate to the work in hand and of modest, unassuming appearance. The general tone of any drawing is greatly improved by well executed lettering, and on the other hand poor, or inappropriate, lettering spoils the appearance, however well the line work be executed.

Legibility is dependent not only upon the type of the lettering, but is even more affected by the spacing of letters and words and whether lower case letters or capitals are used. Words are read not by spelling out the composing letters, but by familiarity with the forms of the words. The body of any written matter, be it in long hand, typewritten, or printed, is in lower case letters, and hence the eye of the reader has become accustomed to the forms of words expressed in lower case letters. It is, then, important that all notes on a drawing be stated in lower case lettering, reserving the use of capitals for headings requiring particular emphasis or titles. Unfortunately some men and some systems advocate the use of capitals for all notes. Such practice is deplorable and is followed only by a small minority of draftsmen.

Ease of execution depends solely upon the type of lettering. Economically any result which is disproportionate to the amount of time and energy required in its accomplishment is undesirable. No thinking person would tolerate an expenditure of four hours in lettering a drawing the rest of whose execution required but two hours. Ornate letters composed of tree limbs with clinging vines, or isometric block letters casting shadows of questionable accuracy, or even so-called mechanical letters laboriously made with the ruling pen and bow compass at the expense of the nervous system of the draftsman, are when used in ordinary drafting, monstrosities which are happily passing into general disrepute. Since the primary purpose of lettering a drawing is to state additional information, no letters are appropriate which detract attention from the drawing itself. The lettering and line work should blend into one harmonious whole, and no form of lettering which is unduly ornate will fulfill this requirement.

29. The Reinhardt Letter.—The system of lettering advocated

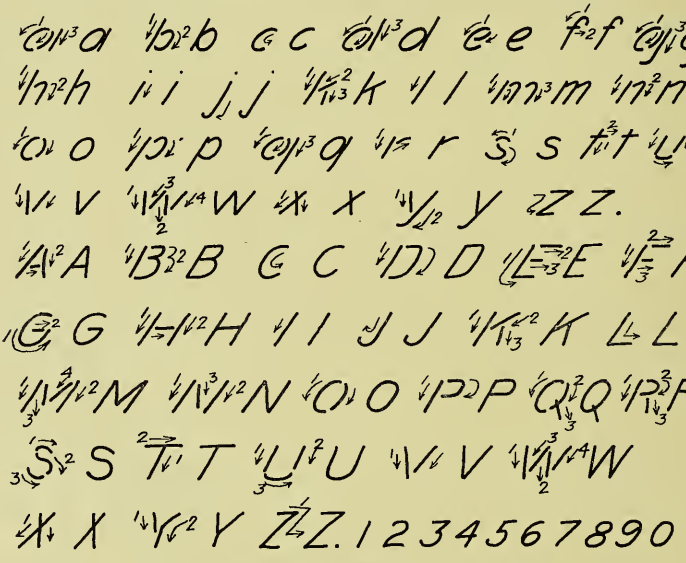


Fig. 33.—Analysis of the Reinhardt letter.

by Mr. Charles W. Reinhart, Chief of the Drafting Department

of the *Engineering News* and first published by him in 1895, is most excellent. Possibly more than anyone else, Mr. Reinhardt has purified engineering lettering and placed it on a sane and firm foundation. His text book on "Lettering" should be in the hands of all draftsmen. In Fig. 33 is shown the Reinhardt alphabet with a brief analysis, the arrows indicating the direction, and the numbers the sequence of the strokes. For a more detailed study of the method of making each letter refer to "Lettering"—C. W. Reinhardt. In the next paragraph a course of lettering is suggested based on this book as a text.

30. Suggested Course in Lettering.—The progress of the student is greatly accelerated if he practices on paper of a suitable ruling such as that shown in the following illustrations.[1] The pen should be held firmly and yet without undue contraction of the fingers. Do not press on the pen point. This statement can not be over emphasized and should be constantly borne in mind. Pressure on the pen point results in lines of varying width, which is far from desirable. Endeavor to keep the slope uniform.

The letters in the following plates are grouped according to similarity of construction rather than in the usual alphabetical order, the grouping of the lower case letters necessarily differing from that of the capitals.

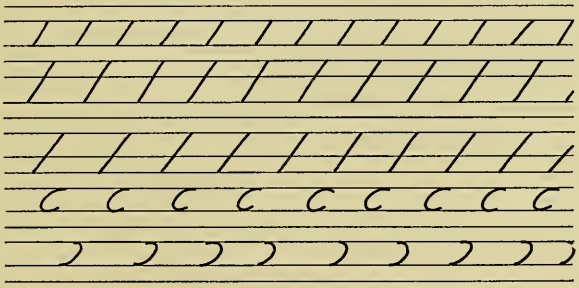


Fig. 34.—Basic strokes in lettering.

[1]Sheets of this ruling have been designed by the author and may be secured of F. Weber and Co., Philadelphia. The over all dimensions are 8″ × 10½″, and inside the border lines, 6″ × 8″.

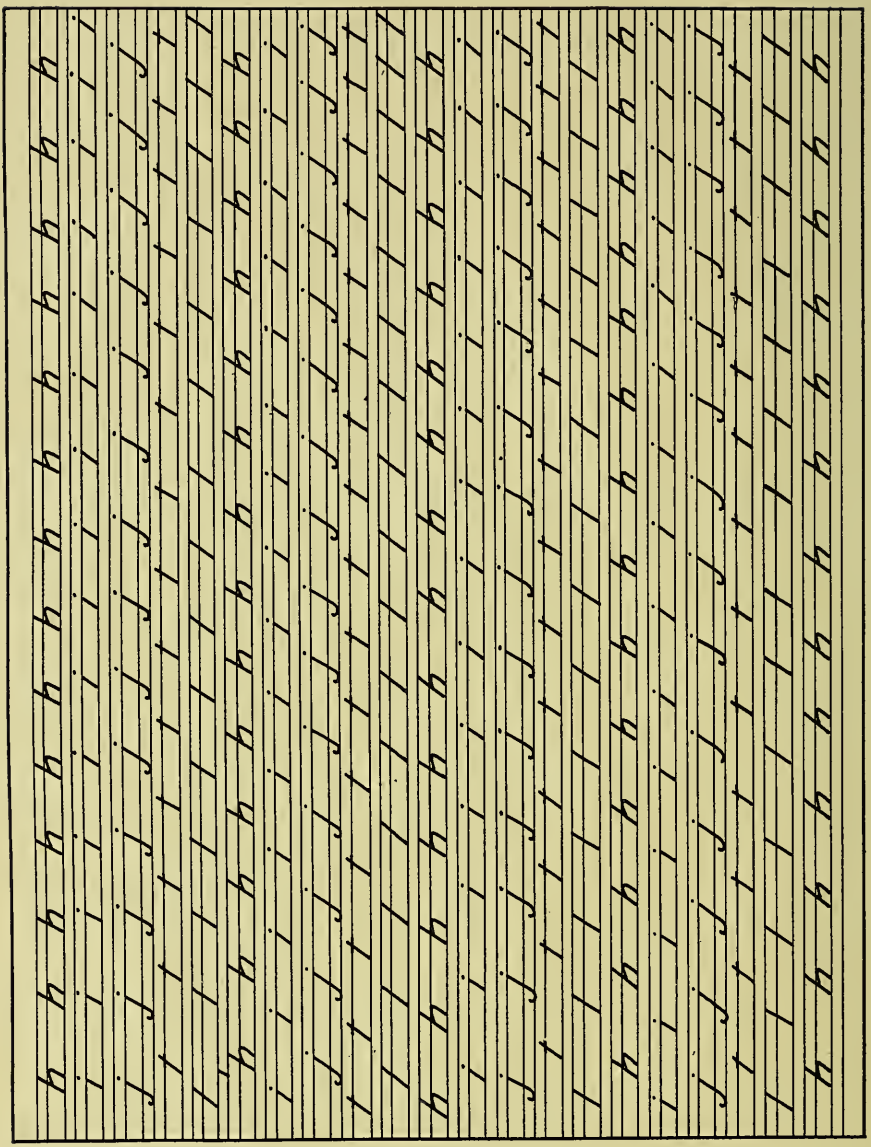


Fig. 35.—Sample lettering plate.

The appearance of a drawing whose workmanship is otherwise excellent may be completely spoiled by poor lettering. In the practical drafting room, the draftsman who letters neatly and rapidly is generally regarded as more valuable than the man whose lettering is mediocre. It is, then, important that the student master a clear, legible style of lettering which can be executed with rapidity. This result can be attained only thoughtful practice combined with a careful study of the form, and method of producing each letter. The first aim of the student should be to make the slope and thickness of the individual lines as uniform as possible without the aid of any mechanical means. Speed should be a secondary consideration though it will follow in due course. Each plate should show an evident improvement over the preceding one

Remember that a moderately skillful hand guided with thoughtful care is a more efficient combination than unusual skill and thoughtless execution. Concentrate your thought on the work in hand

Fig. 36.—Lettering done by a student on entering course in lettering.

The appearance of a drawing whose workmanship is otherwise excellent, may be completely spoiled by poor lettering. In the practical drafting room the draftsman who letters neatly and rapidly is regarded as more valuable than one whose lettering is mediocre. The engineering student should master a style of lettering which possesses these three important features; beauty, legibilty, and ease of execution. This can be accomplished only by a careful study of the form and method of producing each letter, combined with thoughtful practice. After proficiency has been attained in the execution of the individual letters, the attention should be devoted to composition in order that practice may be had in the spacing of letters in words, and words in sentences. The proper spacing is dependent solely upon the taste and judgement of the draftsman.

The student should endeavor to maintain a uniform slant to the letters, and to permit no variation in the weight of the individual lines. A moderately skillfull hand guided with thoughtful care, is a more efficient combination than unusual skill and thoughtless execution.

Fig. 37.—Lettering done by same student after devoting two hours per week for 12 weeks to lettering.

Lower Case Letters.

Plate I consists of the practice strokes shown in Fig. 34. These strokes form the basis of lettering of this character.

Plate II is composed of the letters h, i, j, l, and t. This plate is shown in full in Fig. 35. It will be noted that each letter is given a full line, the lines of letters alternating in the order stated. The following plates are to be treated similarly.

Plate III contains the letters r, k, x, f, y and z.

Plate IV is composed of the letters n, m, u, v and w.

Plate V consists of the letters o, a, e, c and s.

Plate VI contains the letters b, p, d, g and q.

Capital Letters.

Plate VII consists of the letters I, L, F, E and H.

Plate VIII is composed of the letters V, A, K, W, X and Z.

Plate IX contains the letters Y, T, N, M and J.

Plate X consists of the letters U, P, R, D and B.

Plate XI is composed of the letters C, G, O, Q and S.

Numerals.

Plate XII contains the numerals 1, 7, 4, 3 and 2.

Plate XIII consists of the numerals 5, 6, 9, 0, 8.

Composition.

Plate XIV is a copy of the plate shown in Fig. 37.

An interesting record of progress showing the benefit derived from the course may be obtained by having the student on entering the course immediately copy this plate without the slightest help or instruction. A comparison of this first plate with Plate XIV is apt to show almost astonishing improvement. Fig. 36 is the actual reproduction of a beginner's first attempt, and Fig. 37 was executed by the same man three months later.

These two plates are fairly typical of the improvement shown in hundreds of similar tests observed by the author.

Plate XV may consist of any work designated by the instructor such as a title or further work in composition.

This course may be supplemented, if time permits, by a study of vertical lettering. Vertical letters are possibly somewhat clearer than the sloping, but require a longer time in execution, and for general utility are not to be recommended.

31. Composition.—The spacing of letters in words and the spacing of words in sentences is quite as important as the formation of the individual letters. The proper spacing is almost entirely dependent upon the artistic taste of the draftsman. In general keep the letters of a word fairly close together with the white spaces between each letter of uniform size and the spacing between the words equal to about the height of the letter. The judgment and taste of the draftsman are increased with practice, and after the execution of the individual letters has been mastered, considerable attention should be devoted to composition. The student can gain greatly in proficiency by using odd minutes to letter original statements of any kind.

32. Lettering for Architectural Designs and Maps.—The lettering used on these classes of work is permissibly more ornate than would be deemed advisable in machine or structural drawing, and a draftsman who desires more versitality in his lettering should perfect himself in styles of lettering other than the one treated in this chapter. For such study the student is referred to the admirable text. "The Essentials of Lettering," by Professors French and Meiklehohn. In this book useful alphabets are analyzed which have greater beauty and are more adaptable to Architectural and Topographical drawing than the Reinhardt letter. This text is of as great service to the practicing draftsman as to the college student who has completed a course in the Reinhardt system.

CHAPTER IV.

Conic Sections.

33. Cone.—A cone is a solid generated by a right line moving so as constantly to touch a closed curve and pass through a fixed point not in the same plane with the curve. The successive positions of the generating line are elements of the cone and the fixed point is the vertex. The plane of the closed curve is the base of the cone. If the closed curve is a circle the cone is

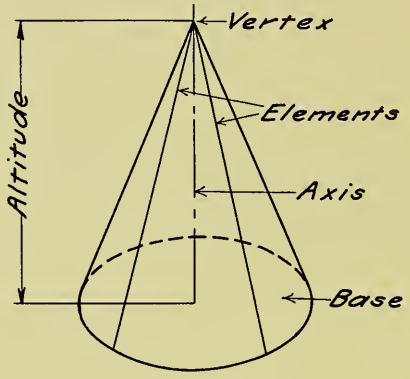


Fig. 38.—Cone.

a circular cone. A line drawn through the vertex to the centre of the base is the axis, and the length of the axis is known as the altitude. If the axis is perpendicular to the base the cone is a right cone.

It is obvious that in a right circular cone all the elements make the same angle with the axis.

34. Cutting Planes.—A right circular cone may be cut by planes at different angles so as to obtain four distinct curves, called conic sections, as follows; a plane perpendicular to the axis cuts a circle, a plane making a greater angle with the axis than do the elements cuts an ellipse, a plane making the same angle with the axis as do the elements cuts a parabola, and finally a plane making a smaller angle with the axis than do the elements cuts

an hyperbola. No curves other than these can be cut from a cone by a plane.

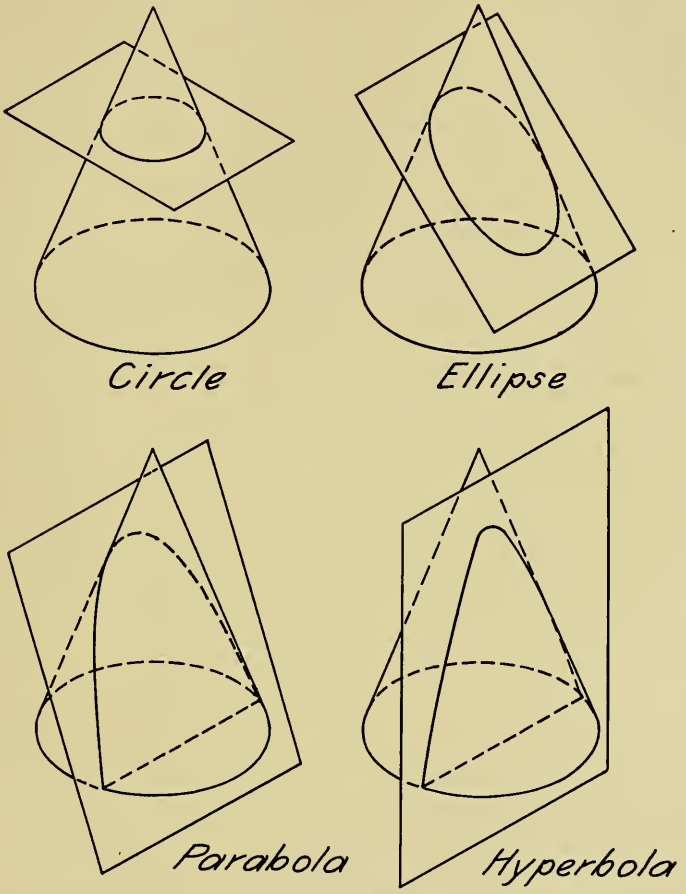


Fig. 39.—Conic sections.

These four curves can be drawn by actually determining the curve cut from the cone by any plane, or by plotting a series of points according to the law known to govern the generation of each curve. Only the latter method will be treated in this chapter.

35. The Circle.—A circle is generated by a point moving in a plane and remaining at a constant distance from a fixed point called the center. The compass is a mechanical device for the drawing of circles and no further discussion of this curve is needed.

36. The Ellipse.—An ellipse is generated by a point moving in a plane so that the sum of its distances from two fixed points, called foci, remains constant.

To Construct an Ellipse. First Method.

Given: The major and minor axes. In Fig. 40 let AA_1 and BB_1 be the major and minor axes, respectively. The foci may be determined as follows: With B as a center and a radius

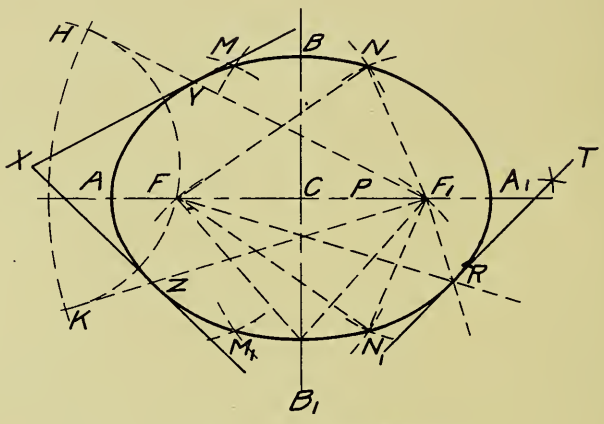


Fig. 40.—Construction of ellipse, first method.

equal to CA_1 (one-half the major axis) describes arcs cutting the major axis in the points F and F_1 which are the desired foci. The sum of the distances from any point on the ellipse to F and F_1 must equal the constant distance represented by the major axis AA_1. The point B (one end of the minor axis) is a point on the ellipse since by construction

$$FB + F_1B = 2A_1C = AA_1.$$

Assume any point on AA_1 lying between F and F_1, such as P. With F as a center and a radius equal to A_1P describe an arc.

With F_1 as a center and a radius equal to AP, describe a second arc cutting the first arc in the points M and M_1. These two points are on the ellipse since

$$MF + MF_1 = AP + A_1P = AA_1.$$

In like manner other positions of P may be assumed and further points of the ellipse obtained.

If it is clearly perceived that the sum of the distances from the foci to one extremity of the minor axis must be equal to the major axis (*i. e.*, $FB + F_1B = AA_1$) no difficulty should exist in plotting an ellipse from any of the following combinations of known data: (1) the major and minor axes, (2) the major axis and one or both foci, (3) the minor axis and one or both foci.

At a given point on the ellipse to construct a tangent: Let R be the given point. Draw RF and RF_1; TR bisecting the angle thus formed is the required tangent.

At a given point outside the ellipse to construct a tangent: Let X be the given point. With F_1 as a center and AA_1 as a radius describe an arc. With X as a center and XF as a radius describe a second arc cutting the first arc in the points H and K. Draw F_1K and F_1H cutting the ellipse in the points Z and Y which are points of tangency. The required tangents are XZ and XY.

To Construct an Ellipse. Second Method.

Given: The major and minor axes. In Fig. 41 let AA_1 and BB_1 be the major and minor axes respectively. With AA_1 and BB_1 as diameters describe two concentric circles and through the center draw any number of radial lines. At the points where the radial lines intersect the smaller circle draw horizontal lines. At the points where the radial lines intersect the larger circle draw vertical lines. The horizontal and vertical lines intersect at points of the required ellipse.

To construct a tangent at any point on the ellipse such as R; draw a tangent to the outer circle at R_1. This tangent produced meets the major axis at T. The required tangent to the ellipse is T R.

37. The Parabola.—A parabola is generated by a point moving in a plane so that its distance from a fixed point is constantly equal to its distance from a given straight line. The given

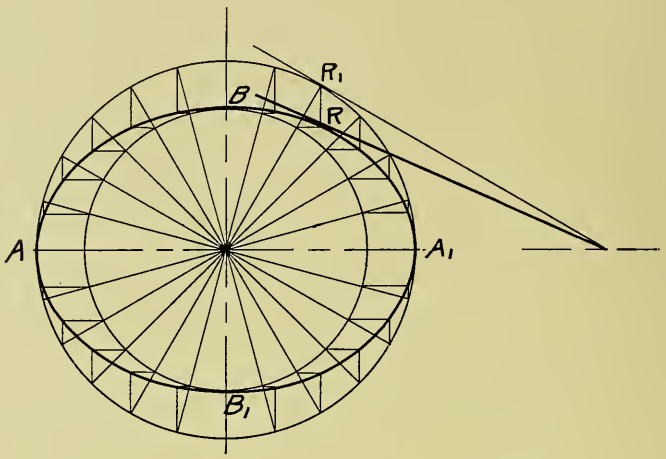


Fig. 41.—Construction of ellipse, second method.

point is the focus and the straight line is the directrix. The axis is a straight line drawn through the focus and perpendicular to the directrix. The vertex is the point of intersection between the curve and the axis, and lies midway between the focus and the directrix.

To Construct a Parabola. First Method, Fig. 42.

Given: The focus and directrix. In Fig. 42, F is the focus, DD_1 the directrix, AA_1 the axis, and V, midway between F and A, is the vertex. At any point on the axis, as P, erect the perpendicular MPM_1. With F as a center and AP as a radius describe an arc cutting the perpendicular through P at the points M and M_1 which are two points on the required curve. The law governing the motion of the generating point is fulfilled since

$$MF = AP = DM$$

Other points, such as N and N_1 may be obtained in like manner.

At a given point on the parabola to construct a tangent: Let N be the given point. Draw NF and NC; TN bisecting the angle thus formed is the required tangent.

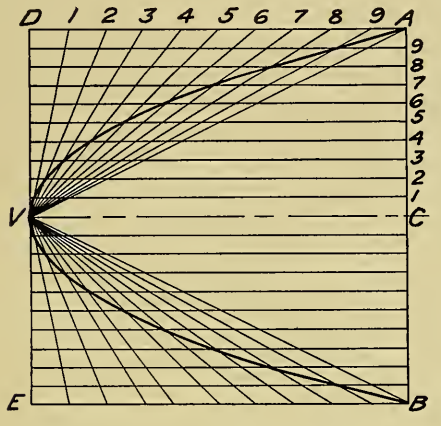


Fig. 42.—Construction of parabola, first method.

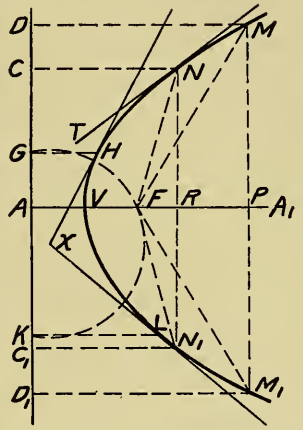


Fig. 43.—Construction of parabola, second method.

At a given point outside the hyperbola to construct a tangent: Let X be the given point. With X as a center and XF as a radius, describe an arc intersecting DD_1 at G and K. Through G and K draw lines parallel to the axis, AA_1, intersecting the curve in the points of tangency H and L. The required tangents are XH and HL.

To Construct a Parabola. Second Method, Fig. 43.

Given: The abscissa VC and the double ordinate AB.

Draw DA and EB equal and parallel to VC, and draw DE parallel to AB. Divide DA and AC into the same number of equal parts. From the divisions on DA draw lines to V and through the divisions on AC draw lines parallel to VC. The lines drawn from corresponding points of division intersect in points on the parabola.

38. The Hyperbola.—An hyperbola is generated by a point moving in the same place so that the difference of its distances from two fixed points remains constant.

To construct an hyperbola: In Fig. 44 let VV_1 represent the constant difference, and let the two foci F and F_1 be the two fixed points so placed that $FV = F_1V_1$.

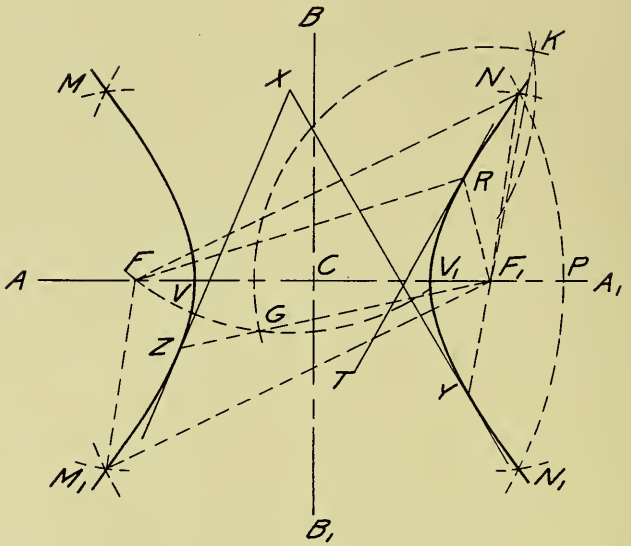


Fig. 44.—Construction of hyperbola.

Draw BB_1, the perpendicular bisector of VV_1. With F as a center and any radius greater than FV_1, as FP, describe an arc. With F_1 as a center and a radius equal to FP—VV_1 describe a second arc cutting the first arc in the points N and N_1. These points will lie on the hyperbola since

$$FP = (FP—VV_1) = VV_1$$

which satisfies the law governing the motion of the generating point. In a similar manner other points may be obtained.

If F_1 is used as a center for the larger radii and F as a center for the smaller, the other branch of the hyperbola will be obtained.

At a given point on the hyperbola to construct a tangent: Let R be the given point. Draw RF and RF_1; TR bisecting the angle thus formed is the required tangent.

At a given point outside the hyperbola to construct a tangent: Let X be the given point. With F_1 as a center and VV_1 as a radius describe an arc. With X as a center and XF as a radius describe the arc FGK cutting the first arc in the points G and K. Draw FK and F_1G cutting the hyperbola in the points of tangency Y and Z. The required tangents are XY and XZ.

If C, the point of intersection of the two axes be taken as the point through which the tangents to the hyperbola are to be drawn, the points of tangency will lie at infinity and the tangent lines will be asymptotes.

CHAPTER V.

Orthographic Projection.

39. Orthographic Projection is the art of representing an object on one or more planes so as to graphically show the lengths and shapes of its lines and surfaces. All working drawings intended to convey exact technical information from the designer to the reader are made in accordance with the principles of orthographic projection. Technical drawing is a graphic language of universal usage, its alphabet and vocabulary being the character of lines, conventions, and symbols previously discussed, and orthographic projection its grammar.

40. Projection on One Plane.—An object is projected onto any desired plane by drawing through the various points of the ob-

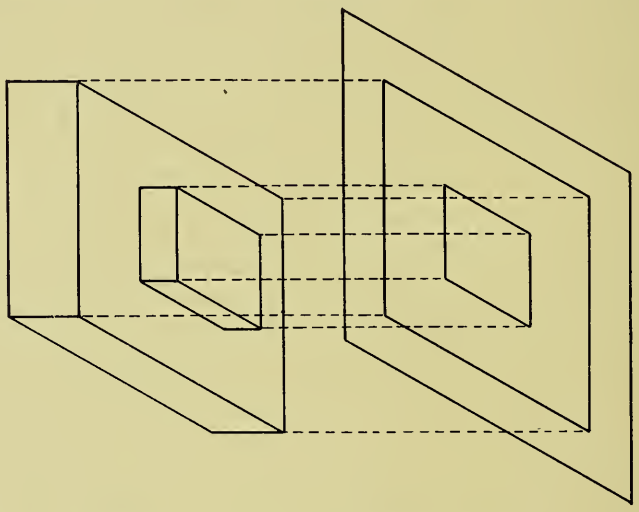


Fig. 45.—Projection of an object onto a single plane of projection.

ject lines perpendicular to the given plane; the points in which these lines pierce the plane are the projections of the corresponding points of the object. The projecting lines are called projectors and the plane onto which the object is projected is the plane of projection. Thus in Fig. 45 the object has been projected onto

tht plane as shown. The resultant projection represents the object as it would appear if viewed from in front, the point of sight being an infinite distance away. This view alone describes only the front face of the object and gives no information as to the

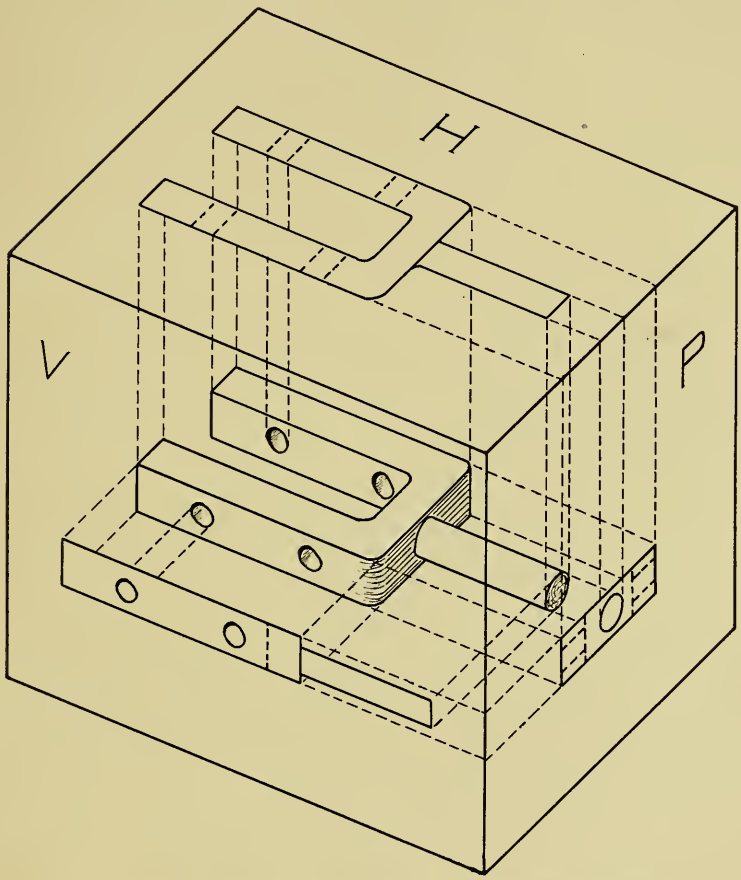


Fig. 46.—Cast iron fork projected onto three planes of projection.

shape of the top and sides. In order, therefore, to completely represent any object it must, in general, be projected onto three different planes, thus showing three views. The planes are generally placed so as to be mutually perpendicular (as the top,

front and side of a box), the resultant projections showing the object as though viewed successively from the top, front and side.

41. Projection on Three Planes.—In Fig. 46 is shown a cast iron fork surrounded by three planes which may be regarded as transparent. The top plane lettered **H** is called the horizontal plane of projection, the plane in front lettered **V** is called the vertical plane of projection, and the plane at the side lettered **P** is called the profile plane of projection. By letting fall from the object lines perpendicular respectively to each of these planes, three views of the fork are obtained. The projection on the **H** plane represents the fork as it would appear were the observer looking down upon it; the projection on **V** represents the fork as though viewed from in front; and the projection on **P** represents the fork as though viewed from the side. These three views graphically describe all lines and surfaces of the fork, and taken in conjunction give the three dimensions, length, breadth and thickness.

The line of intersection between the **H** and **V** planes is known as the ground line and is lettered GL. The line of intersection between the **P** and **V** planes is lettered XY.

It is obviously impossible for the draftsman to actually draw on three mutually perpendicular planes. He is limited to the one plane as represented by his drawing paper. Some method, then, must be used for bringing the three planes containing the three views into one plane. This is accomplished as shown in Fig. 47 by raising the **H** plane about GL as an axis until it is coincident with **V**, and revolving the **P** plane to the right about LY as an axis until it also is coincident with **V**. The three views are now found on one plane, the top view above the front view and the side view at the right of the front view. In practice the draftsman, though employing mentally the process here given, does not draw the three planes but shows only the three views as given in Fig. 48. In Fig. 48 it should be noted that LX and LX_2 are revolved positions of the same line, LX_1.

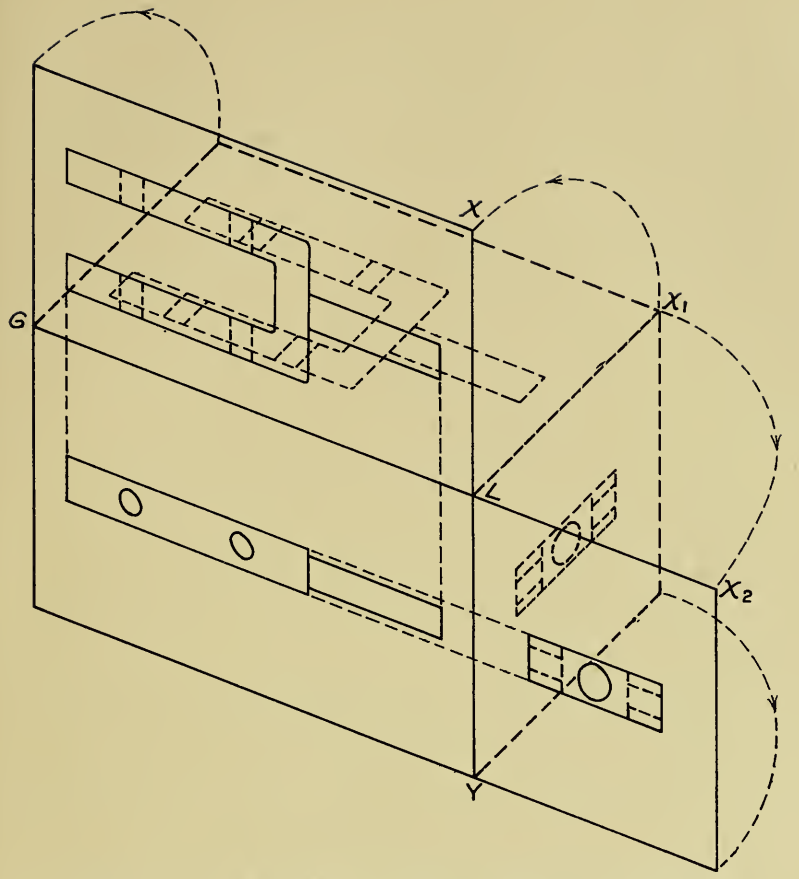


Fig. 47.—The three planes of projection opened to form one plane.

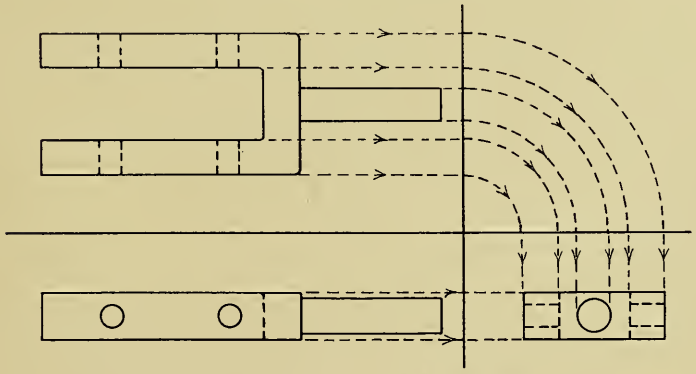


Fig. 48.—Top, front and side views of a cast iron fork.

A dotted line is used to signify the invisibility of the line represented. A line may be invisible in one view and visible in another.

42. Fundamental Principles.—From the foregoing discussion and figures the following important principles are evident:

1. If a line is perpendicular to a plane its projection on that plane is a point.

2. If a line is parallel to a plane its projection on that plane will be parallel to the line.

3. If a surface is perpendicular to a plane its projection on that plane is a line.

4. If a surface is parallel to a plane its projection on that plane will show the true size and shape of the surface.

5. The top and front views of any point lie in the same vertical line.

6. The front and side views of any point lie in the same horizontal line.

7. The side view of any point is as far from XY as is the top view from GL.

43. Sequence of Views.—In general it is advisable to first construct that view most of whose lines are shown in true length. Let it be desired to show three views of the square based wedge illustrated in Fig. 49. It is evident that all lines of the base as well as the edge AB are parallel to **H** and hence the top view will be first constructed. At any convenient distance above GL draw a square, equal in size to the base of the wedge, and in the center draw a line equal to the length of the edge AB. The top view is now completed by connecting the ends of the edge with the corners of the square.

The front view is a triangle whose base is equal in length to a side of the square, and whose altitude is equal to the height of the wedge. All points of the front view must lie vertically

under the corresponding points of the top view (Art. 42. Rule 5).

To obtain the side view draw XY at any convenient distance to the right of the front view. Draw horizontal lines from the

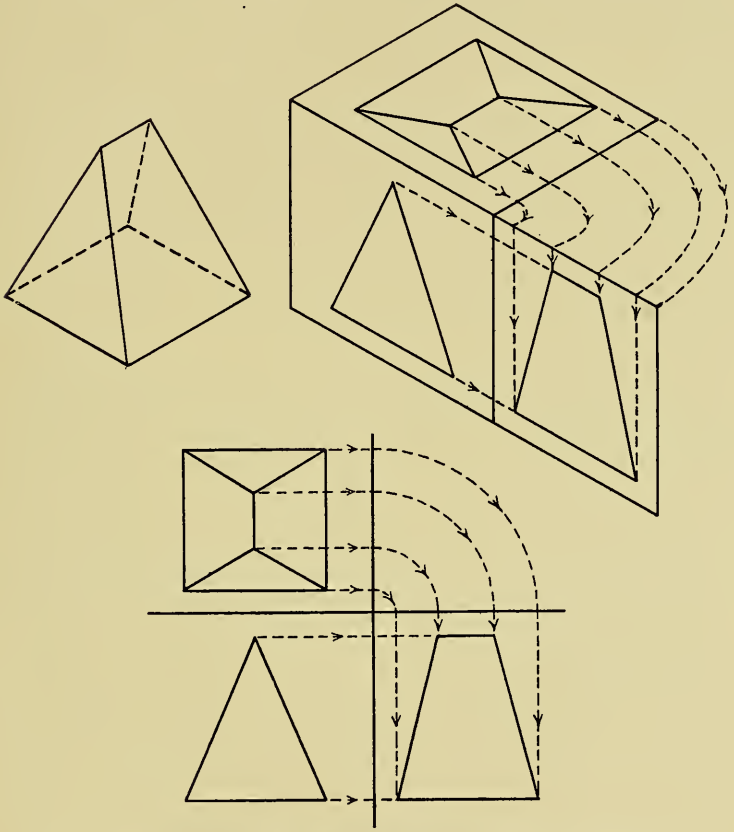


Fig. 49.—Three views of a wedge, pictorially showing method of obtaining side view.

top view to XY, revolve to the right to meet GL, and let fall perpendicular lines. These perpendiculars intersect horizontal lines drawn from corresponding points of the front view in the desired points of the side view.

The student should never lose sight of the fact that the top, front and side views have been made on mutually perpendicular planes, and from these three views a mental conception of the entire object is gained.

As an aid in properly locating the various points of an object, the points of the top view are lettered a, b, c. etc., the corresponding points of the front view a′, b′, c′, etc., and the corresponding points of the side view a^p, b^p, c^p, etc. In actual drafting practice the points of a drawing are not lettered nor are the projecting lines shown. Also the center lines of the various views are made to serve the purpose of the ground line (GL) and the profile plane trace (XY). Until, however, the student has thoroughly mastered the principles of orthographic projection, he will find it greatly to his advantage to letter all critical points, draw all projecting lines, and to draw and letter GL and XY.

A few illustrative problems will now be considered.

44. To Obtain the Top, Front and Right Side View of a Hollow Cylinder. Fig. 50.

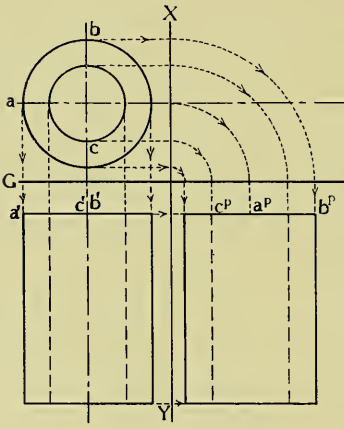


Fig. 50.—Hollow cylinder axis perpendicular to *H*.

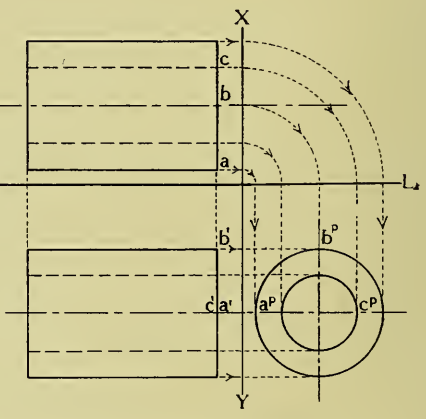


Fig. 51.—Hollow cylinder axis perpendicular to *P*.

Given: The altitude and the outer and inner diameters of the cylinder; the axis of the cylinder to be perpendicular to H.

The top view consists of two concentric circles of the given diameters.

For the front view construct a rectangle whose width is equal to the diameter of the larger circle and the altitude equal to the given altitude. Within this rectangle construct a second rectangle of equal altitude but whose width is equal to the diameter of the smaller circle. The limiting lines of the inner rectangle are invisible and hence are dotted.

The right side view is identical with the front view; or it may be obtained by projecting the points of the top view onto XY, revolving to meet GL, and letting fall perpendiculars to meet horizontal lines drawn through the corresponding points of the front view.

45. To Obtain the Usual Three Views of a Hollow Cylinder. Fig. 51.

Given: As in the preceding problem except that the axis is perpendicular to **P**.

Since the axis of the cylinder is perpendicular to **P** the center lines of the rectangles forming the top and front views are parallel to GL.

The construction of the three views is obvious.

46. To Obtain the Usual Three Views of a Cone. Fig. 52.

Given: The diameter of the base and the altitude; the axis to be perpendicular to **H**; the apex pointing towards **H**.

The top view consists of a circle whose diameter is equal to the given diameter of the base.

The front view is an isosceles triangle whose base is equal to the given diameter and the altitude equal to the given altitude of the cone.

The side view is identical with the front view, or it may be constructed by the indicated revolution.

47. To Obtain the Top, Front and Left Side Views of the Frustrum of a Cone. Fig. 53.

Given: The altitude and the diameters of each of the bases; the axis perpendicular to **P**; the larger base nearer the profile plane.

The top and front views are identical, each one consisting of a trapezoid of the given altitude, the two ends being equal in length to the given diameters of the bases.

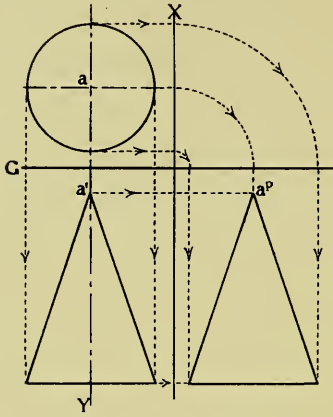


Fig. 52.—Cone axis perpendicular to *H*.

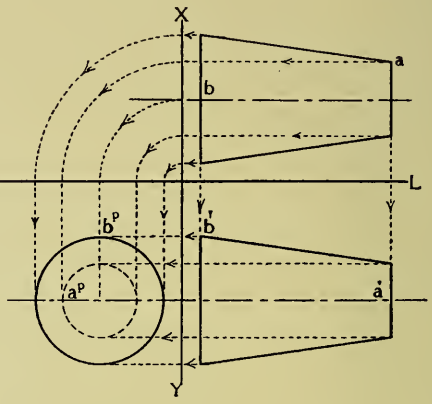


Fig. 53.—Frustrum of a cone, axis perpendicular to *P*.

The left side view may be obtained by placing the profile plane at the left and revolving the points of the top view counterclockwise as shown. The result of this revolution is two concentric circles with diameters equal to the given diameters of the bases. The smaller base is not visible from the left and hence the inner circle is dotted.

48. To Obtain the Top, Front and Right Side Views of a Hexagonal Prism. Fig. 54.

Given: The altitude, and the size of the base; the axis to be perpendicular to **H**; two faces parallel to **V**.

The top view consists of a regular polygon of given size, two sides being parallel to GL.

The construction of the front and side views is obvious. Note that in the front view the edges m'n' and k'l' are invisible but coincide with the visible edges c'd and e'f' respectively. A similar case occurs in the side view.

In Fig. 55 is shown three views of the same hexagon except that two faces are now perpendicular to **V**.

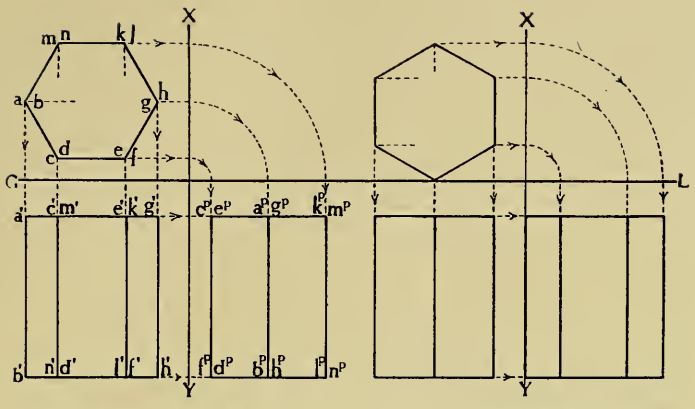


Fig. 54.—Hexagonal prism two faces parallel to *V*.

Fig. 55.—Hexagonal prism two faces perpendicular to *V*.

49. To Obtain the Usual Three Views of a Hexagonal Prism. Fig. 56.

Given: The altitude, and the size of the base; the axis to be perpendicular to **P**; no face to be either parallel or perpendicular to **H** or **V**.

It is evidently more convenient to first construct the side view.

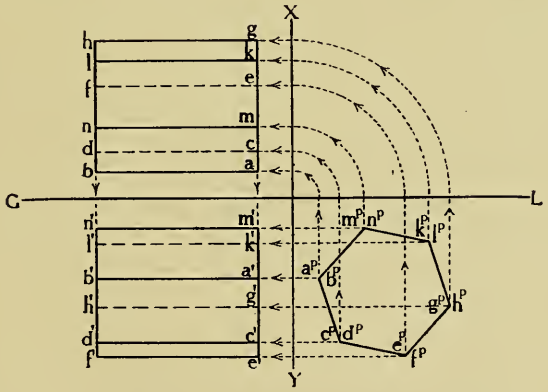


Fig. 56.—Hexagonal prism axis perpendicular to *P*.

To construct the side view; at any convenient distance be-

tween GL and to the right of XY draw a regular hexagon no side of which is either parallel or perpendicular to GL or XY.

To construct the top view; project the points of the side view to GL, revolve counter-clockwise to XY, and draw ab, cd, etc., equal in length to the given altitude. The lateral edges CD and EF are invisible when viewed from above **H** (that is, when looking down on the side view from above GL), hence cd and ef are dotted. The top view is completed by drawing ga and gb.

To construct the front view; project the points of the top view downward to meet horizontal lines drawn from the corresponding points of the side view. The lateral degrees GH and KL are invisible when viewed from in front of **V** (that is, when looking at the side view from the left of XY), hence g'h' and k'l' are dotted.

50. Revolution.—In the foregoing illustrations the objects were situated in the simplest position relative to the planes of projection, that is, with as many lines as possible parallel to **H**, **V** and **P**. This is the natural way of placing an object and would be the one chosen were the choice left to the convenience of the draftsman. It is sometimes necessary, however, to represent an object with axis oblique to one or more of the planes of projection.

Conceive three lines passed through the object and intersecting at its center, one of the lines being perpendicular to **H**, the second perpendicular to **V**, and the third perpendicular to **P**. The object may be brought into obliquity with any desired plane of projection by revolving the object about the proper one of the foregoing three lines as follows:

First, the object may be revolved about the line perpendicular to **H**, which has the effect of turning it on its base to the right or left.

Second, it may be revolved about the line perpendicular to **V**, causing the object to lean to the right or left.

Third, it may be revolved about the line perpendicular to **P**, causing the object to tip forward or backward.

If an object be represented in its simplest position and is then revolved in any one of the foregoing ways, two views will be changed while the third view will remain identical with the corresponding view of the object in its original position. **The unchanged view will lie on that plane of projection to which the axis of revolution is perpendicular and should be the first view constructed.**

In Fig. 57 are shown three views of a wedge in its simplest position . The arrow points are placed on the projecting lines to indicate the direction in which they were drawn.

In Fig. 58 the wedge has been revolved from its original position through an angle of 45° to the right about an axis perpen-

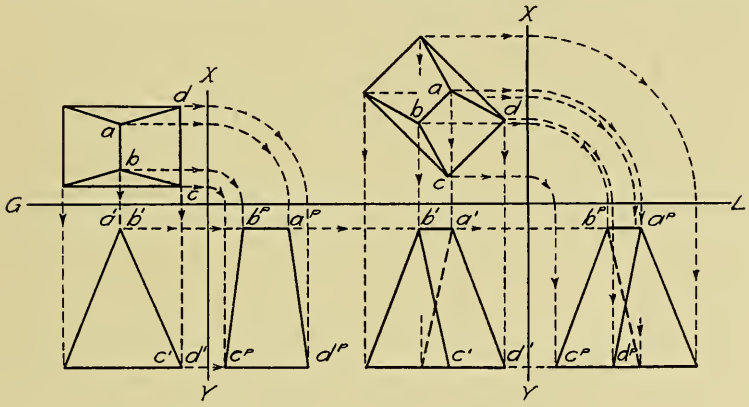


Fig. 57. Fig. 58.

Wedge revolved about an axis perpendicular to *H*.

dicular to **H**. The top view is identical with the top view of Fig. 57, except that the sides make an angle 45° with GL. During this revolution all points of the wedge remain the same distance from **H**. Hence the front view of Fig. 58 is constructed by letting fall perpendicular lines from points of the top view to meet horizontal lines drawn from corresponding points of the front view of Fig. 57. The side view is constructed in the usual manner.

In Fig. 60 the wedge has been revolved from its original position through an angle of 45° to the right about an axis perpen-

dicular to **V**. The front view is identical with the front view of Fig. 59 except that it leans to the right at an angle of 45°. During this revolution all points of the wedge remain the same dis-

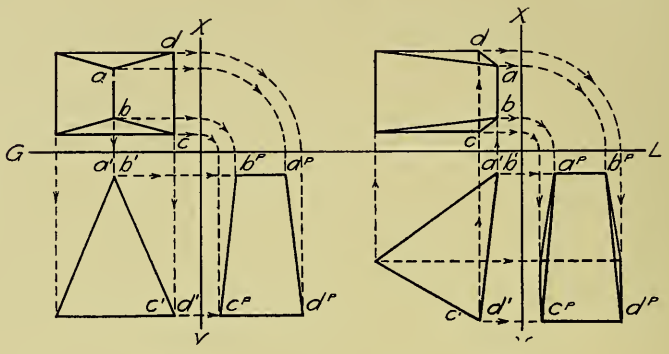


Fig. 59. Fig. 60.

Wedge revolved about an axis perpendicular to *V*.

tance from **V**. Hence the top view is constructed by erecting perpendicular lines, from the points of the front view, to meet horizontal lines drawn from corresponding points of the top view of Fig. 59. The side view is constructed in the usual manner.

In Fig. 62 the wedge has been revolved from its original position backward through an angle of 30° about an axis perpendicular to **P**. The side view is identical with the side view of Fig. 61 except that it tips backward. During this revolution all points of the wedge remain at the same distance from **P**. Hence the top view is constructed as follows: From points on the side view erect perpendiculars to GL, revolve to XY, and draw horizontal lines to meet vertical lines let fall from corresponding points on the top view of Fig. 61. The front view is obtained by drawing horizontal lines from points on the side view to meet vertical lines let fall from corresponding points of the top view.

Careful attention is needed to ascertain those lines which are invisible and hence dotted.

51. Successive Revolutions.—In the problems of Art. 50 the initial position of the wedge was the same before each revolu-

tion. It is sometimes necessary for the draftsman to revolve an object about a certain axis, and from that position to again revolve it about a second axis, and possibly to again revolve it about a third axis. In this manner the object can be placed in any conceivable position relative to the planes of projection. No

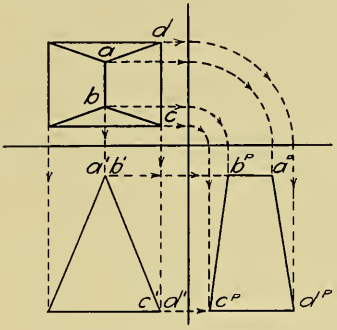


Fig. 61.

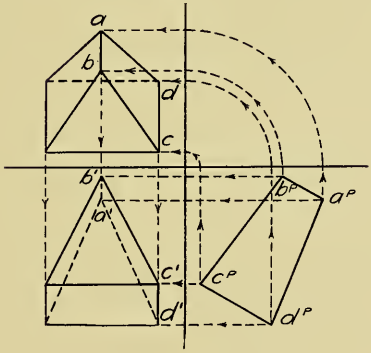


Fig. 62.

Wedge revolved about an axis perpendicular to *P*.

principles are used in successive revolutions other than those developed in the preceding articles.

In Fig. 63 is shown the original position of a pyramid and its successive revolutions about axes perpendicular to **H**, **V** and **P** respectively. In revolving about the axis perpendicular to **V**

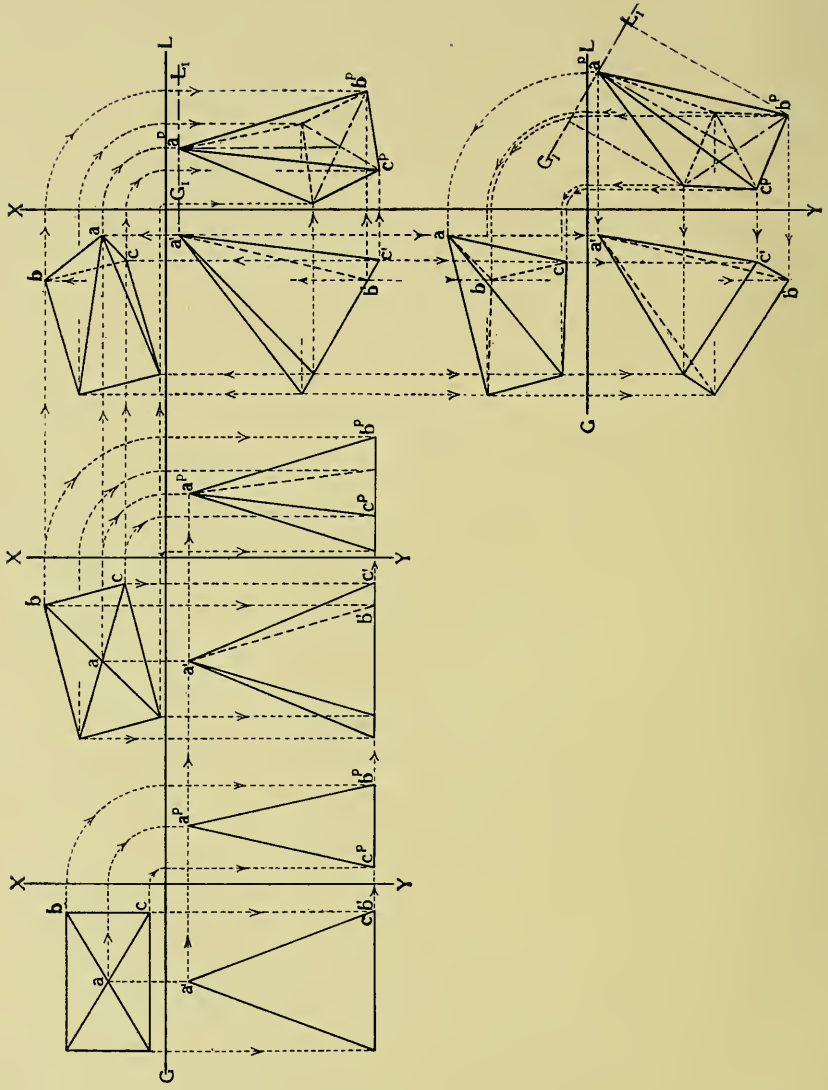


Fig. 63.—Wedge revolved successively about axes perpendicular to H, V and P.

the front view is identical with the front view immediately preceding, the other two views being constructed in the usual manner.

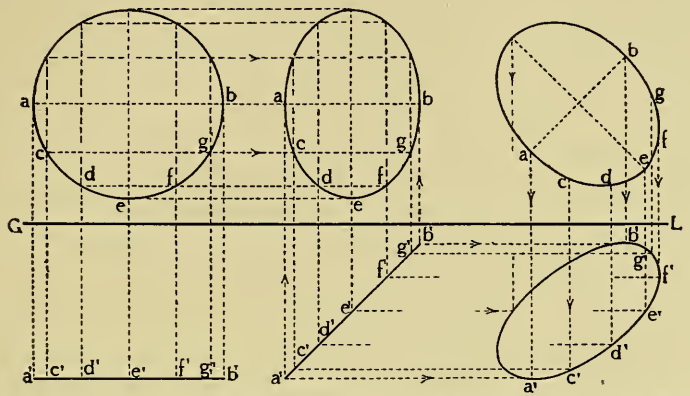


Fig. 64.—Circle revolved successively about axes perpendicular to *V* and *H*.

In revolving about the axis perpendicular to **P** the side view is identical with the side view immediately preceding. The auxiliary line $G_1 L_1$ is used as an aid in reproducing this view.

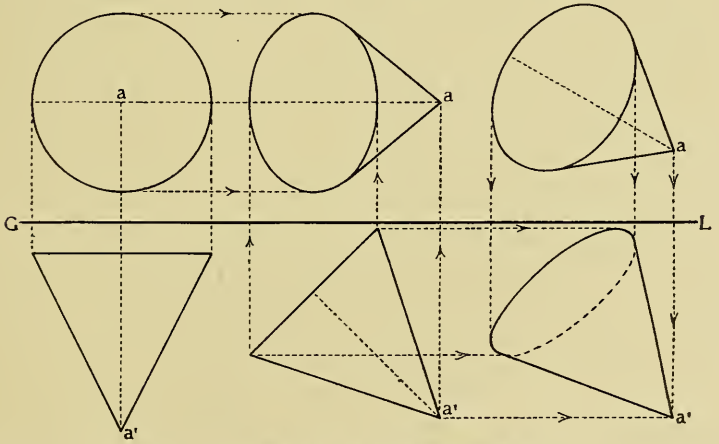


Fig. 65.—Cone revolved successively about axes perpendicular to *V* and *H*.

In Fig. 64 the original position of the circle is parallel to **H** and perpendicular to **V**, the top and front views only being

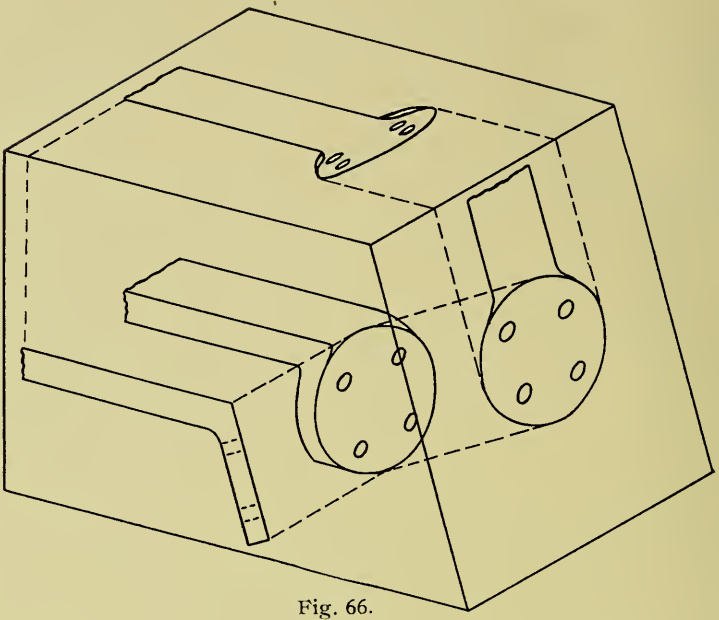


Fig. 66.

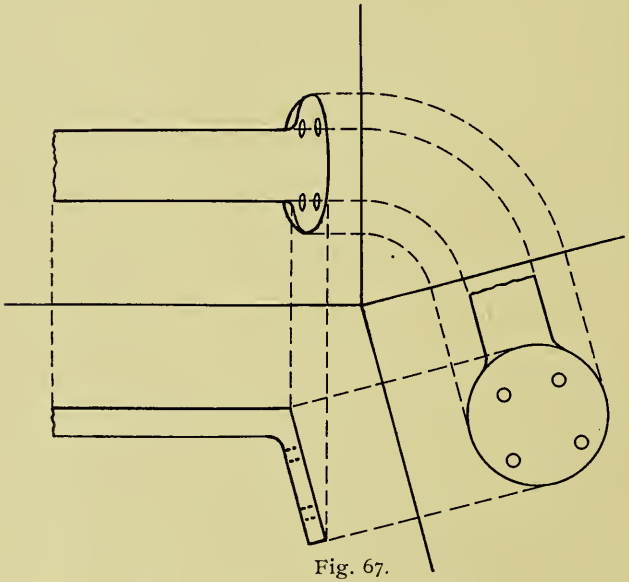


Fig. 67.

Auxiliary plane of projection.

shown. The circle is then revolved about an axis perpendicular to **V.** The front view remains a straight line but is inclined to GL at any desired angle. The top view is constructed in the usual manner. The circle is now further revolved about an axis perpendicular to **H.** The top view is identical with the preceding top view except that the axis makes any desired angle with GL. The front view is constructed as usual.

In Fig. 65 is shown a cone which has been successively revolved about an axis perpendicular to **V** and about an axis perpendicular to **H.** The original position of the cone was taken so as to make the base parallel to **H,** the apex pointing downward from **H.**

52. Oblique Plane of Projection.—An object is sometimes encountered which can not be placed so that all of its faces are parallel to the three planes of projection. One face, at least, may be oblique and this face may be best shown by projecting it onto an auxiliary parallel plane. The projection on this parallel plane will show the true shape and size of the face. A case of this kind is illustrated in Fig. 66, the orthographic projection being shown in Fig. 67.

It is frequently sufficient to project only the oblique face onto

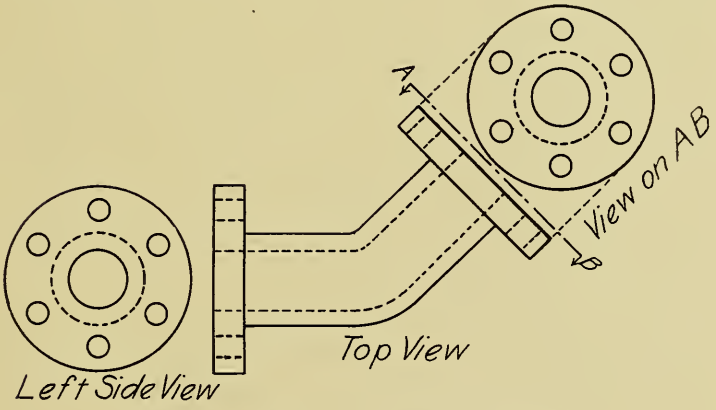


Fig. 68.—Auxiliary end view of pipe elbow.

the auxiliary plane and to disregard, in that view, all other lines of the object. Thus in Fig. 68 only the oblique flange is projected

onto the parallel plane whose line of intersection with **H** is AB. The auxiliary plane is then revolved about AB as an axis until coincident with **H**.

53. Sectional Views.—The internal construction can sometimes be shown to best advantage, by passing an imaginary cutting plane through the object and theoretically removing that part of the object which lies between the observer and the cutting plane. In Fig. 69 is shown a top view and a vertical section of

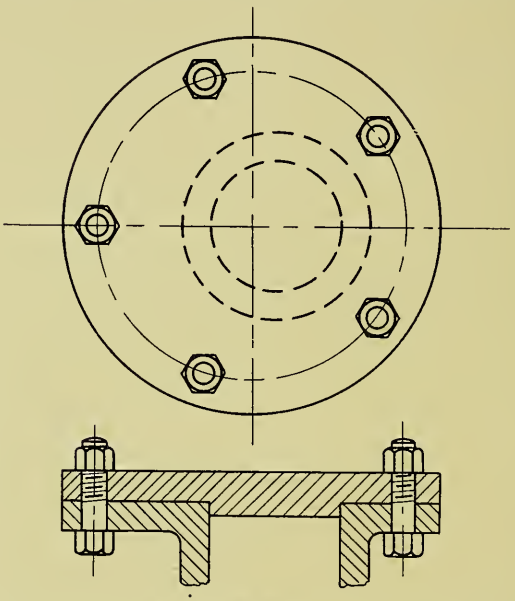


Fig. 69.—Top view and cross section of a cylinder cover.

a cast iron cylinder and cover. Note that the cutting plane passes through two bolts but that these bolts are not cross hatched. It is an idiom of the graphic language that bolts, arms of pulleys, webs, keys, shafts, and gear teeth are never cross hatched. Moreover in Fig. 55 only two bolts are shown in section, whereas it is obvious that five could be seen in the sectional view. The location of these bolts, however, is clearly shown in the plan and their position in the sectional view would appear peculiar and confusing. Practical utility warrants the statement that the

sectional view should show only that data which conveys useful information and discard all else even though pure theory would require it to be shown.

The cross section of a pulley is shown in Fig. 70. The arm is

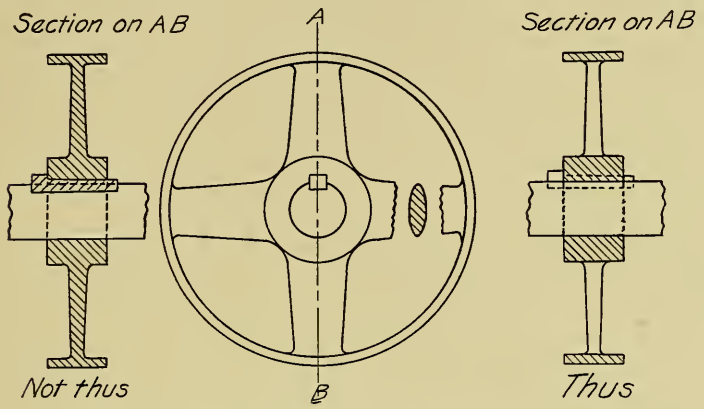


Fig. 70.—Front view and cross sections of a pulley.

not cross hatched but the shape is shown by a separate section revolved into the plane of the paper.

The draftsman may legitimately make use of the fact that an

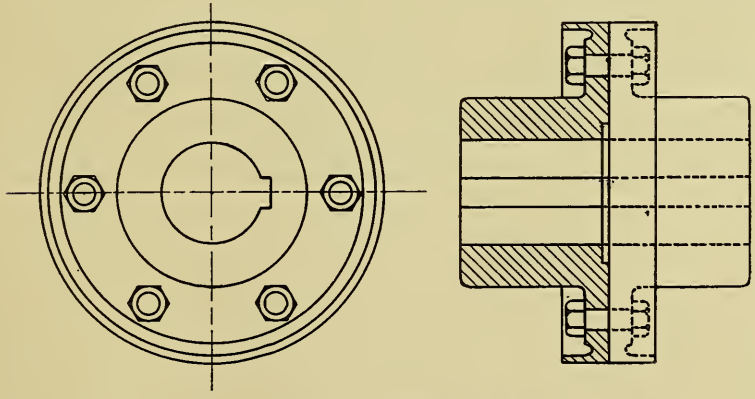


Fig. 71.—Top view and half section of a Hill coupling.

object is symmetrical about a certain axis, by showing one-half

the view full and the other half in section. Fig. 71 illustrates this practice.

It is sometimes convenient to represent only a small part of a surface as removed in order to show in section the construction

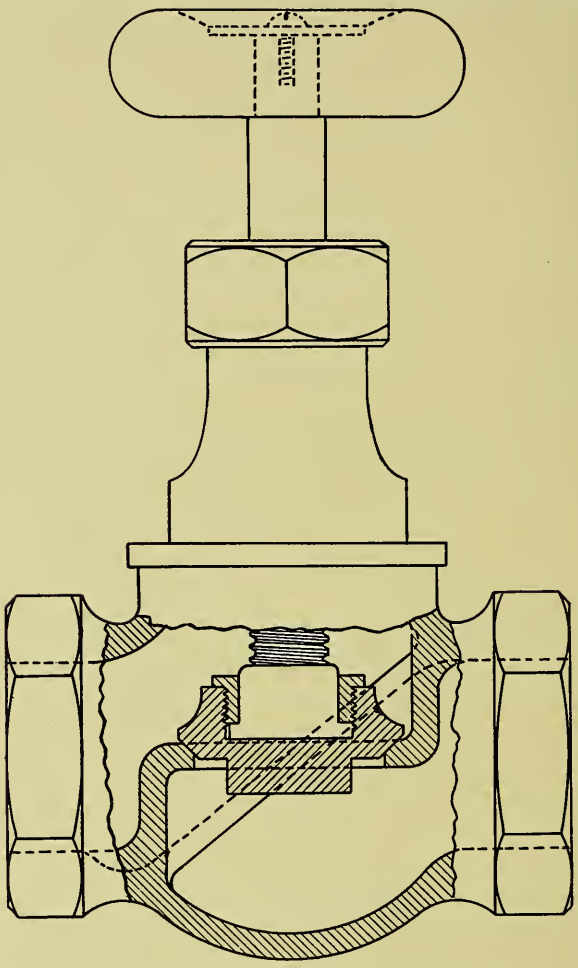


Fig. 72.—Globe valve showing broken section.

lying beneath. Such a view is called a broken section and is illustrated in Fig. 72.

PROBLEMS.

Geometric Solids.

Each of the following problems may be placed in a space 5″ x 5″. The layout of a plate which is adaptable to spaces of this size is shown in the appendix.

The expression "three views" is understood to mean the top, front and side views.

1a, 1b, 1c. Draw three views of a hollow cylinder, Fig. 73, with (a) axis perpendicular to **V**; (b) axis perpendicular to **H**; (c) axis perpendicular to **P**.

2a, 2b, 2c. Draw three views of a cone, Fig. 73, (a) axis perpendicular to **V**, apex towards **V**; (b) axis perpendicular to **H**, apex away from **H**; (c) axis perpendicular to **P**, apex towards **P**.

3a, 3b, 3c. Draw three views of a square based pyramid, Fig. 73, (a) axis perpendicular to **V**, apex away from **V**; (b) axis perpendicular to **H**, apex towards **H**; (c) axis perpendicular to **P**, apex away from **P**.

4a, 4b, 4c. Draw three views of a hexagonal pyramid, Fig. 73, (a) axis perpendicular to **V**, apex towards **V**; (b) axis perpendicular to **H**, apex away from **H**, no side of the base parallel or perpendicular to **V**; (c) axis perpendicular to **P**, apex towards **P**, two sides of the base perpendicular to **V**.

5a, 5b, 5c. Draw three views of a triangular pyramid, Fig. 73, (a) axis perpendicular to **V**, apex away from **V**, no side of the base parallel to **H**; (b) axis perpendicular to **H**, apex towards **H**, one side of the base parallel to **V**; (c) axis perpendicular to **P**, apex towards **P**.

6a, 6b, 6c. Draw three views of a hexagonal prism, Fig. 73, (a), (b) and (c) as in problem 4.

7a, 7b, 7c. Draw three views of a wedge, Fig. 73, (a) short edge nearest **H**, long side of base parallel to **V**; (b) base parallel to **V**, short edge farthest from **V**, short side of base parallel to **H**.

8a, 8b, 8c. Draw three views of a triangular prism, Fig. 73, (a) axis perpendicular to **V**; (b) axis perpendicular to **H**; (c) axis perpendicular to **P**.

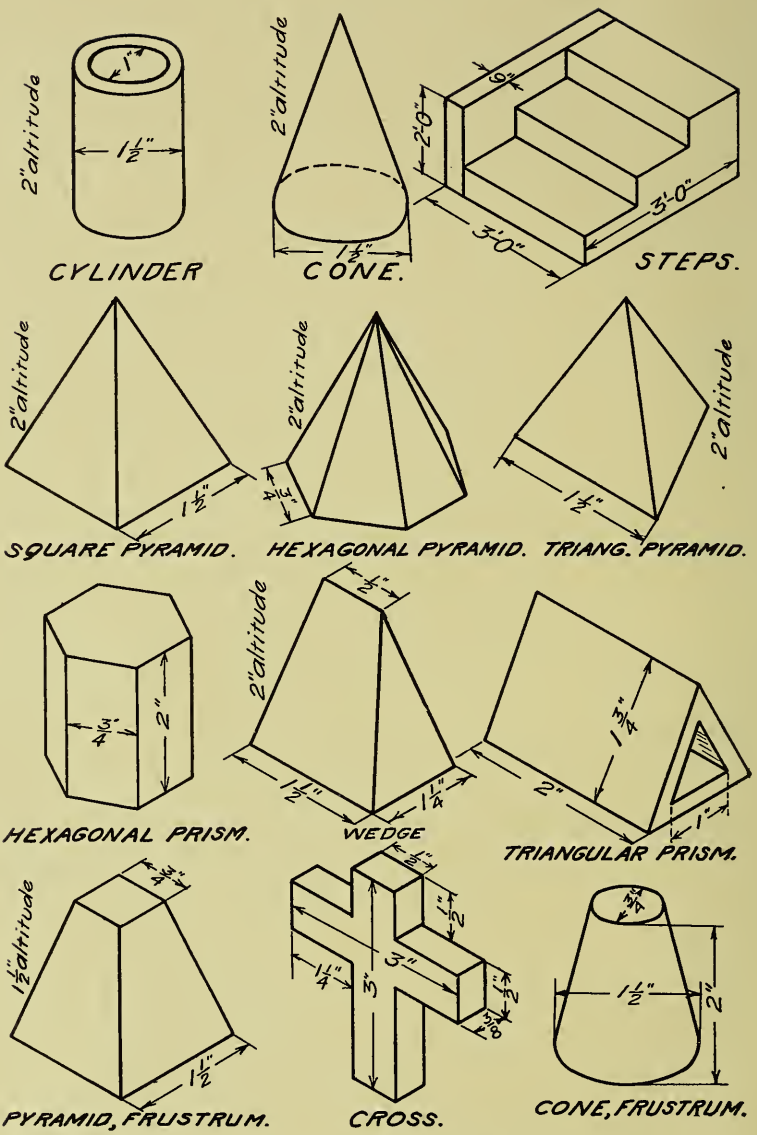


Fig. 73.—Geometric objects.

9. Draw three views of a flight of steps, Fig. 73. Scale 1″ = 1′-0″.

10a, 10b, 10c. Draw three views of a frustrum of a square based pyramid, Fig. 73, (a) axis perpendicular to **V**, small base nearest **V**; (b) axis perpendicular to **H**, large base nearest **H**; (c) axis perpendicular to **P**, large base nearest **P**.

11a, 11b, 11c. Draw three views of a cross, Fig. 73, (a) face marked "A" nearest **V**; (b) "A" nearest **H**; (c) "A" nearest **P**.

12a, 12b, 12c. Draw three views of a frustrum of a cone, Fig. 73, (a), (b) and (c) as in problem 10.

Machine Details.

13. Draw top and front views of a monkey wrench, Fig. 74. Scale

14. Draw front view and longitudinal section of a bearing, Fig. 74. Scale

15. Draw three views of a bracket, Fig. 74. Scale

16. Draw three views of a support, Fig. 74. Scale.

17. Draw an end view and longitudinal section of a flange connection, Fig. 75. Half size.

18. Draw three views of a pivot, Fig. 75. Half size.

19. Draw three views of a bearing, Fig. 75. Scale 3″ = 1′-0″.

20. Draw three views of a pedal, Fig. 75. Scale 1½″ = 1′-0″.

21. Draw the top, front, and auxiliary plane view of a lever, Fig. 76. Scale 3″ = 1′-0″. (Break the rod in order to shorten length.)

22. Draw three views of a rod support, Fig. 76. Scale 3″ = 1′-0″.

23. Draw three views of a packing gland, Fig. 76. Half size.

24. Draw three views of a lever support, Fig. 76. Full size.

Revolution.

An entire plate had best be devoted to each of the following problems. If a plate of the size shown in the appendix is used, each group of three views will be placed in a rectangle 5″ x 7½″.

25. Draw three views of a wedge, Fig. 73, axis perpendicular to **H**, short edge nearest **H**, and long side of base parallel to **V**,

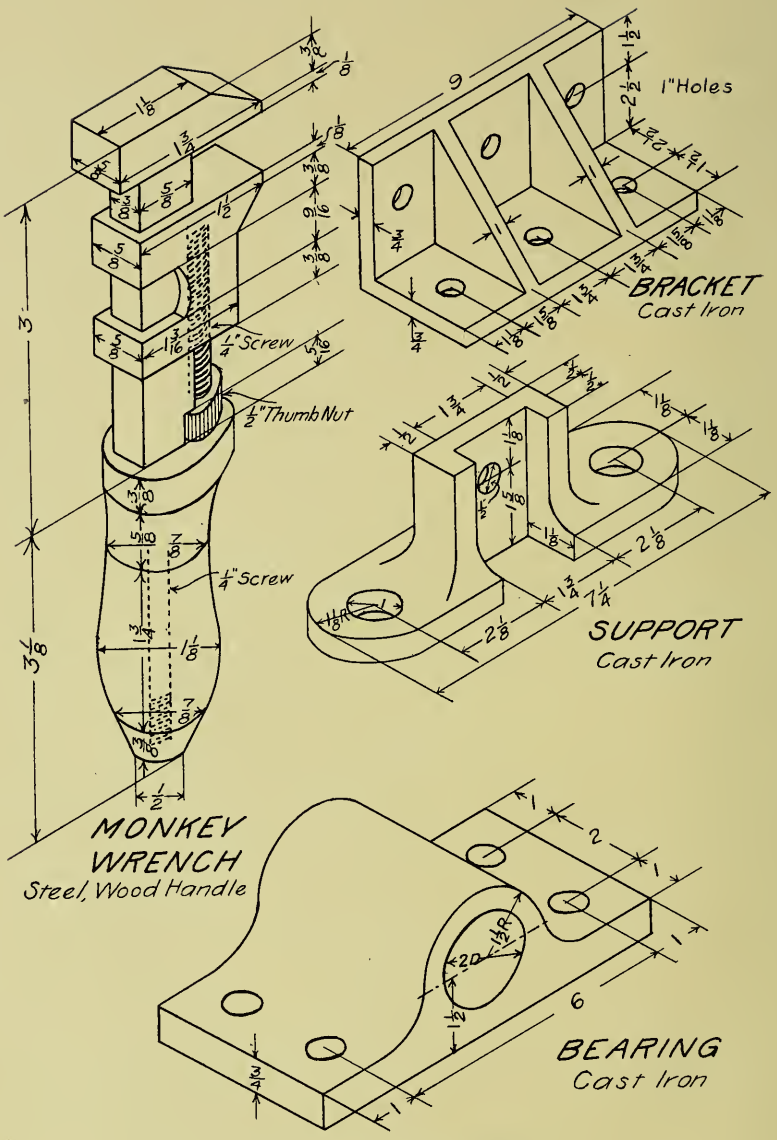


Fig. 74.—Machine details.

and revolve it (a) through an angle of 15° to the right about an axis perpendicular to **H**; (b) through an angle of 45° to the left about an axis perpendicular to **V**; (c) forward through an angle of 45° about an axis perpendicular to P.

26. Draw three views of a hexagonal prism, Fig. 73, axis perpendicular to **H**, two sides of the base parallel to **V**, and revolve it (a) 30° to the right about an axis perpendicular to **V**; (b) 30° to the right about an axis perpendicular to **H**; (c) 30° forward about an axis perpendicular to **P**.

27. Draw three views of a hexagonal pyramid, Fig. 73, according to the instructions given in problem 26.

28. Draw three views of the frustrum of a pyramid, Fig. 73, axis perpendicular to **H**, large base nearest **H**, two sides of base parallel to **V**, and revolve it (a) 30° to the left about an axis perpendicular to **H**; (b) 45° to the left about an axis perpendicular to **V**; (c) 45° forward about an axis perpendicular to **P**.

29. Draw three views of a triangular prism, Fig. 73, long side parallel to **H** and **V**, and revolve it (a) 30° to the right about an axis perpendicular to **H**; (b) 60° to the left about an axis perpendicular to **V**; (c) 45° backward about an axis perpendicular to **P**.

30. Draw three views of a square pyramid, Fig. 73, axis perpendicular to **H**, two sides of the base parallel to **V**, and revolve it (a) 15° to the right about an axis perpendicular to **H**; (b) 45° to the left about an axis perpendicular to **V**; (c) 60° forward about an axis perpendicular to **P**.

Successive Revolution.

31. Draw three views of a hollow cylinder, Fig. 73, axis perpendicular to **P**, and revolve it (a) 30° to the right about an axis perpendicular to **H**; (b) from the position obtained in (a) revolve 45° to the left about an axis perpendicular to **V**; (c) from the position obtained in (b) revolve 30° backward about an axis perpendicular to **P**.

32. Draw three views of a cone, Fig. 73, axis perpendicular to **H**, apex nearest **H**, and revolve it (a) 45° to the right about an axis perpendicular to **V**; (b) from (a) revolve 60° to the left

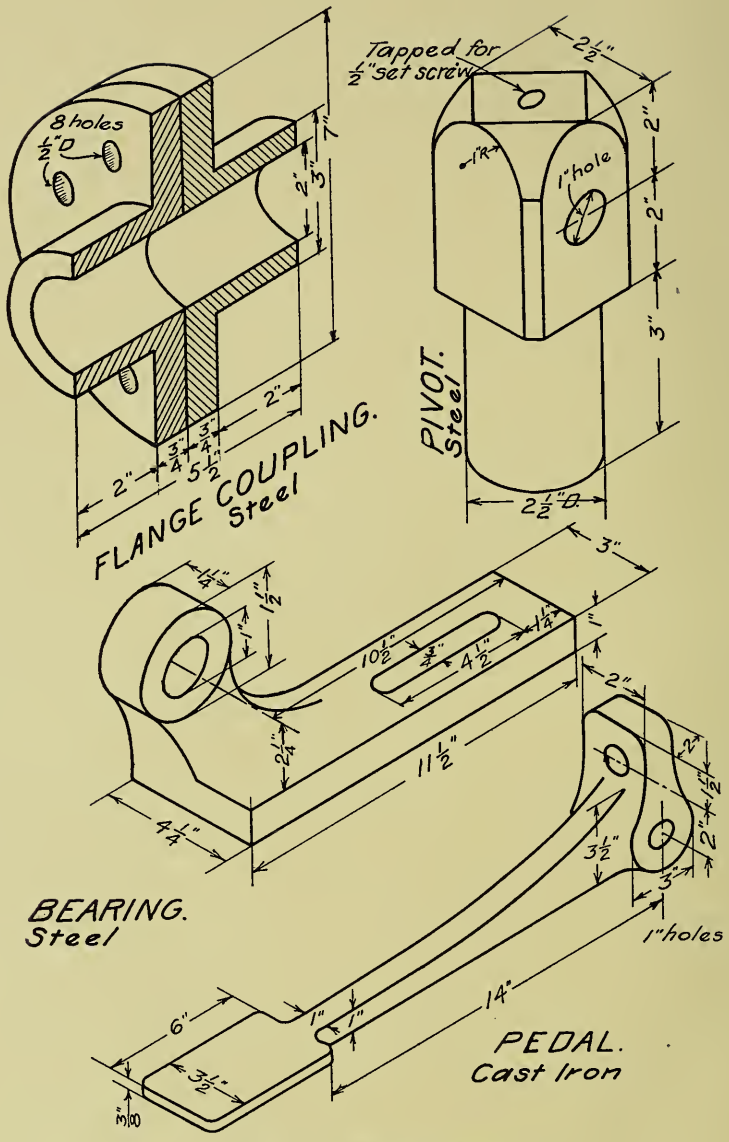


Fig. 75.—Machine details.

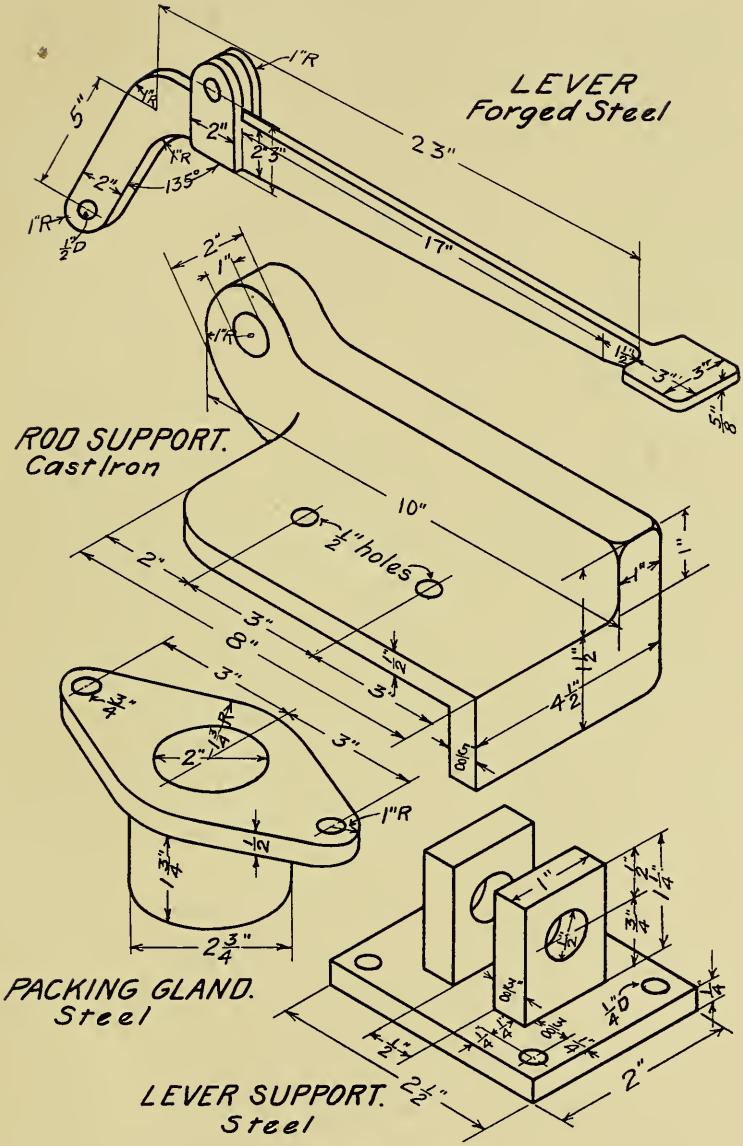


Fig. 76.—Machine details.

about an axis perpendicular to **H**; (c) from (b) revolve 30° forward about an axis perpendicular to **P**.

33. The same as problem 25 except that the revolutions are to be continuous.

34. The same as problem 26 except that the revolutions are to be continuous.

35. The same as problem 27 except that the revolutions are to be continuous.

36. The same as problem 28 except that the revolutions are to be continuous.

37. The same as problem 29 except that the revolutions are to be continuous.

38. The same as problem 30 except that the revolutions are to be continuous.

Auxiliary Views.

39. Draw the top and front views of the given object in its simplest position. Obtain an auxiliary view projected onto a plane parallel to an inclined face.

a. Wedge.
b. Triangular prism.
c. Square pyramid.
d. Hexagonal pyramid.
e. Frustrum of a square pyramid.

The foregoing objects are dimensioned in Fig. 73.

CHAPTER VI.

Working Drawings.

54. Clearness.—It has been previously stated that practically all working drawings are made in accordance with the principles of orthographic projection. The purpose of such a drawing is to give clearly all the information needed to construct the object represented. A drawing which does not fulfill this purpose is a failure, however artistic it may be in appearance and accurate in execution. Failure to clearly express the design is, in general, due to one of two main causes; either the information is not complete, due to an omitted view, dimension line, or note, or the information may be confused by an excess of data such as too many views, several separate notes pertaining to the same matter with possible confliction, needlessly repeated dimensions, or confusing lines due to a rigid adherence to the laws of projection. Lack of sufficient data is due partly to carelessness on the part of the draftsman and partly to his failure to theoretically place himself in the position of the one who is to use the drawing in order to ascertain if all needed information has been given. Excess of data, the second cause for failure in clear expression, is due partly to the mistaken belief that no idioms exist in graphic language, and partly to an inherent verbosity of expression whether the language be English or graphic. To a great extent this matter is solely one of common sense and the following rules are offered merely as a general guide:

1. Show only as many views as are necessary to completely portray the object.

2. Do not repeat dimensions on one view which are clearly shown on another.

3. Do not treat the same subject matter in several scattered notes.

4. Written notes, figured dimensions, and the graphic line work must all be so clearly expressed as to render vagueness or ambiguity impossible.

5. If, in any particular case, a law of projection conflicts with

clearness, sacrifice the letter of the law and stick to clearness which is, in reality, the spirit of all laws of projection.

The draftsman who is thoroughly aware of the fact that the fundamental test of any drawing is its readableness cannot go far astray.

The rules just suggested, as well as other means to secure simple and clear expression, will be discussed in subsequent articles of this chapter.

55. Assembly and Detail Drawings.—Working drawings are divided into two main divisions, assembly drawings and detail drawings.

The purpose of the detail drawing is to portray each part of the machine or structure separately. The details may all be placed on one drawing with the name of the piece under each detail; or, if there are many details, one drawing may consist solely of castings, another of forgings and still another of bolts and screws. Due to the probable great variance in size of the different pieces, it is frequently desirable to use several scales on the same detail drawing. In such a case the scale should be placed under each piece drawn. If all the pieces on one drawing are to be made from the same material, the name of the material is placed in the title. If various materials are represented on the same sheet, the material should be stated under each piece, and the title should read "Material as indicated." A "Bill of Material" is generally placed on each drawing, which is a tabulation of the name, material, and number required, of each piece. One column is usually left for remarks. Some firms prefer to omit the Bill of Material from the drawing and place it on a separate sheet which accompanies the drawing.

An assembly drawing is a representation of the machine or structure as a whole with its various pieces in their proper places. On such a drawing is shown only the over-all dimensions and the distances from center to center of the various pieces in order that the drawing may be of service in erecting the machine or structure.

If the object represented is sufficiently simple the assembly and detail drawings may be combined. In such a drawing each

piece is completely represented and dimensioned and yet shown in its proper place in relation to the other pieces.

56. The number of views required to completely represent an object will vary from two to possibly five or six. In general, the top, front and side views are required, though many simple objects may be clearly shown in two views. Frequently the top view and a cross section give an ample description, or the top view and front view. When only two views are shown the side view is seldom one of the two. A more complicated object may require the top, front, right and left side views, a view on an auxiliary plane, as well as several cross sections. The only guide in this matter is to remember that the machine or structure must be clearly and completely represented in as few views as possible.

It has been previously shown that the logical arrangement of views requires that the front view be under the top view, and the side view at the left or right of the front view. This arrangement should be adhered to rigidly. In this connection it is of interest to note that the English practice is to regard the object as being above the horizontal plane and in front of the vertical plane. The planes are brought into coincidence by revolving the profile plane backward to coincide with the vertical plane, and lowering the horizontal plane until coincident with the vertical plan, the front view thus being shown above the top view and the side view at the right of the front view. This system has but little to recommend it and was discarded in the United States some twenty years ago. It is still used in England, though at various times attempts have been made to change to the system used in this country.

57. Notes.—The language of graphics should be supplemented by the English language whenever additional clearness can be gained by so doing. Sometimes a well worded note will save the making of a view. The note should be lettered in lower case letters and should be so clearly expressed that a vague or ambiguous interpretation is impossible.

58. Dimensioning.—The neat, accurate, and legible dimensioning of a drawing is as important a part of the drawing as the

actual graphic representation of the various views. In dimensioning a working drawing the draftsman must assume the point of view of the artisan who is to construct the object represented and give those dimensions which will best aid in the construction. The well equipped draftsman should have a working knowledge of the general methods used in pattern-making, casting, forging, and machine shop practice, in order that his designs may be constructed economically.

The following rules for dimensioning represent the accepted practice of most modern drafting rooms:

1. Dimension lines should be fine, continuous, black lines with an open space near the center for the insertion of the figures.

2. Draw all dimension lines before inserting the figures.

3. Figures should always read from the bottom or right side of the drawing.

4. Arrow points should be neatly made and should touch the lines between which the dimension is given.

5. Dimension only between center lines and finished surfaces.

6. Do not give a dimension between dotted lines if it can be avoided.

7. The total sum of a series of dimensions (called an "over-all" dimension) should always be given.

8. Do not require the user of a drawing to add or subtract in order to obtain a desired distance.

9. Do not repeat a dimension on one view which is clearly shown on another. Divide the dimensions between the various views by selecting the dimensions best suited to each view.

10. Dimension lines should not be crowded close to other lines of the drawings, but should be placed clearly and conspicuously.

11. In general place the dimension lines outside the view. Occasionally clearness may be gained by violating this rule.

12. Do not place dimension figures on a center line or on a line of the drawing.

13. Give diameters of circles and radii of arcs, and abbreviate diameter to Dia. or D. and radius to Rad. or R.

14. Locate holes by giving dimensions to their center lines.

15. Dimensions of less than two feet should be given in inches, as 17″, 23″, and two feet and over in feet and inches, as 2′-0″, 3′-7″.

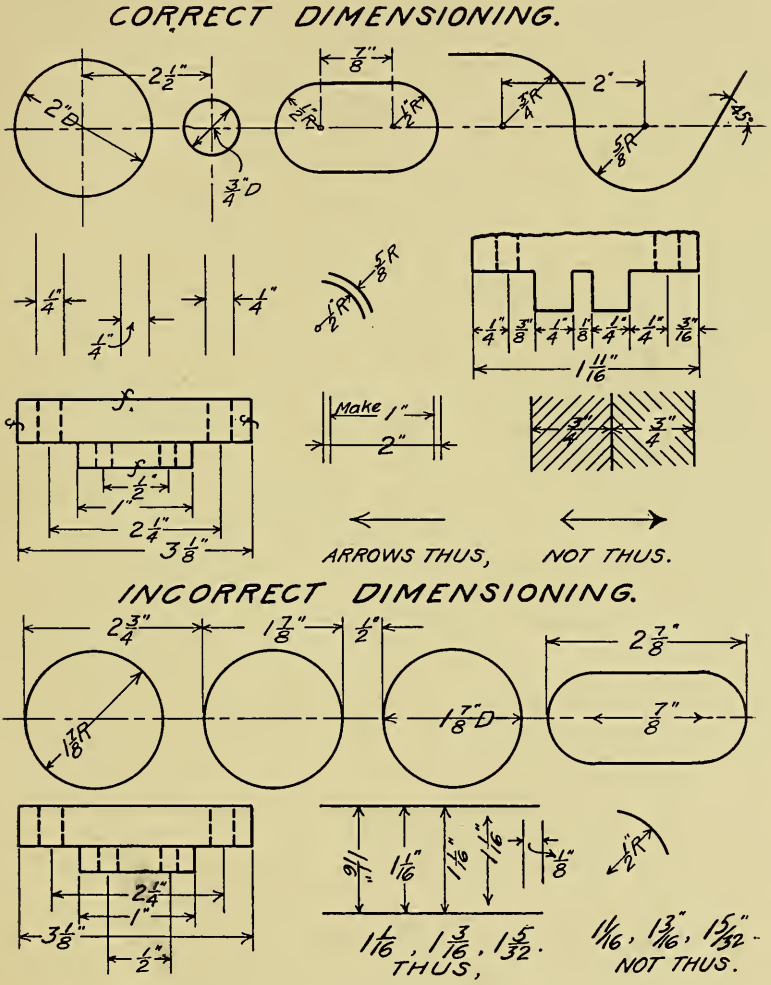


Fig. 77.—Correct and incorrect dimensioning.

An exception to this rule is almost universally made in the case of shafts, pulleys, gears, wheels, wheel-base, cylinders, and pipes,

this class of work being dimensioned in inches only, as 121″ wheel-base, 48″ pipe, 60″ pulley, etc.

16. The dividing line of a fraction should be made horizontal.

17. The figures should read parallel to the length of a dimension line and not perpendicular to it.

18. If a dimension does not agree with the scaled distance, due to a change after the drawing has been made, underline the dimension figures or prefix the work "make." In this manner the draftsman indicates his knowledge of the discrepancy.

19. Never cross hatch over a dimension figure.

20. The cutting plane of a section should be shown by a dot and dash line and lettered. At each end of the line show by arrows from which side of the cutting plane the section is viewed. Mark the sectional view thus: Section on AB.

21. To indicate that a surface is to be machined or "finished" an f is placed on that view of the surface which shows as a line. If all surfaces of the object are to be finished letter under the piece "finish all over" or the abbreviation "f. a. o." This latter statement is made in the title if applicable to all pieces represented on the drawing. Otherwise the title should read "Finish as indicated."

In Fig. 77 many of the foregoing rules are illustrated as well as some additional forms of dimensioning. This figure should be carefully studied. The primary cause for stating a dimension in one form rather than in another is increased clearness.

59. Title.—The title is placed in the lower right hand corner of the sheet. The amount of space devoted to the title and the size of the letters depends upon the size of the drawing. For drawings 12″ x 18″, 18″ x 24″ and 24″ x 36″, the rectangular space reserved for the title may be 3½″ x 2½″, 4¼″ x 3″ and 5″ x 3½″ respectively. The lettering of the title should be free hand, vertical preferred, and of such a size as will artistically fill the space reserved. Nearly every engineering firm has its own standard title containing such information as is most suitable for the requirements of that particular firm. Many firms print the standard form for the title onto the tracing cloth, others use a

rubber stamp, while still others leave the construction of the title entirely to the draftsman. Various titles have been designed for various needs so that it is impossible to give a form sufficiently general to cover all requirements. The following data is, however, included on most title forms:

1. Name of the firm.
2. Name of machine or structure.
3. Scale.
4. Drawn by ——, traced by ——, checked by ——.
5. Approved by ——.
6. Date; usually that of completing tracing.
7. Number; for filing purposes.

In small detail drawings the material and finish are sometimes included in the title. A characteristic free hand title is illustrated in Fig. 74.

60. Checking.—Before leaving the drafting room, a drawing should be carefully examined by someone other than the drafts-

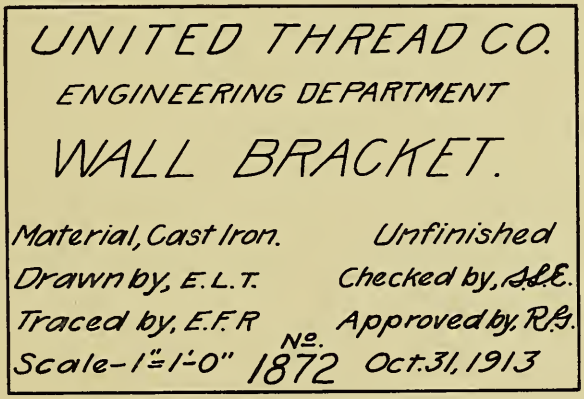


Fig. 78.—Typical title.

man who executed it. In large drafting rooms "checkers" are employed whose sole duty is the examination of drawings. In smaller drafting rooms the draftsmen check each others work. The checker, by signing his name to the drawing becomes responsible for the accuracy and correctness of the work. The fact

that a drawing is to be examined by a professional checker does not relieve the draftsman from the necessity of carefully and thoroughly examining his own work before turning it over to the checker. A drawing should be examined systematically according to some standard outline such as the one here suggested:

1. Before checking any details read the drawing as a whole to see if the general meaning is clear.

2. See if a sufficient number of views are given to clearly represent each piece, and that there are no unnecessary or confusing views.

3. See that the material, finish, and scale for each piece are properly stated.

5. Carefully examine all dimensions to ascertain, that all necessary dimensions are clearly shown; that there are no superfluous ones; that scaled distances agree with the given dimensions; that no arrow points are omitted; and that all dimensions are placed to the best advantage.

6. Check all computations, and see that there is a sufficient amount of clearance wherever clearance is required.

7. See that, wherever possible, standard sizes of bolts, screws, pipes, shafting, etc., have been specified.

8. See that notes are briefly and clearly expressed.

The student before handing in a plate should apply the foregoing examination and in addition should farther check his work to see, (1) that wherever an erasure has been made all lines affected have been re-inked; (2) that all visible lines are full and all invisible lines are dotted; and (3) that his name, date, number, and plate number are on the drawing. When the student finally hands in his plate at the office it is the equivalent of saying in words, **"This plate has been executed with all the care and conscientious work of which I am capable. It is a true measure of my present ability as a draftsman."**

61. Sketching.—The ability to rapidly execute a neat, readable sketch is essential to the engineer or draftsman. Those men whose time is valuable frequently express the general idea of a

design by means of a free hand sketch, leaving the execution of the working drawing to a draftsman. A good engineer can express his ideas as fluently, and even more clearly, by sketching than by talking. The draftsman is frequently required to make sketches of existing machinery which may be at some distance from the drafting room, and from these sketches to make the working drawings. It is this phase of sketching which will be discussed in this article.

In sketching from an object these tools are necessary; paper (preferably cross section paper), a 3H pencil, a two-foot folding rule, and a pair of calipers. The sketch should be made entirely free hand, but its neatness and accuracy are limited only by the ability of the draftsman. The making of a sketch should be divided into three distinct parts as indicated by the following paragraphs.

Views.—First decide on those views which will best illustrate the object. Sketch the views decided upon, judging relative lengths solely by the eye but as accurately as ability permits. Remember that too many views are better than not enough, since on the ultimate working drawing unnecessary data can easily be discarded.

Dimension Lines.—After having made the requisite views place dimension lines on the sketch but do not fill in the dimension figures. A more systematic and thorough dimensioning of the sketch is insured in this way, than by diverting the attention to actually measure distances and fill in the figures. The danger at this point of the work is that not a sufficient number of dimension lines will be used. Regard the various views critically and see that a dimension line is placed wherever it will be needed in the making of the final drawing. Draw all center lines and extension lines while placing the dimension lines. It will be noted that up to this point of the work handling of the object, which is apt to be greasy, oily, or dusty, is unnecessary, thus insuring a neater, cleaner, sketch than would be the case were the object handled frequently and needlessly.

Dimension Figures.—By means of the two-foot rule and cali-

pers obtain the dimensions from the object and record them in the proper dimension lines previously placed.

It should be remembered that the sketching may be done at some distance from the drafting room, and that omitted data will cause trips to and from the drafting which should be regarded as an ignominious loss of time. Therefore the completed sketch should be subjected to a rigid examination, checking its various views and dimensions along the lines explained for working drawings in article 60. A well executed sketch should be susceptible of translation into a complete working drawing by a draftsman other than the sketcher.

62. Shade Lines.—The shade line is a heavy weight line used to indicate which surfaces are raised and which are depressed. Shade lines undoubtedly lend a touch of realism to the flatness of orthographic projection, and their use is to be commended whenever the gain in clearness is sufficient to compensate for the additional time required in execution. Some drafting rooms prohibit absolutely the use of shade lines, while a smaller number require shade lines to be used on all drawings. Neither of these extreme systems is to be recommended. It is not a matter to be settled by a fixed and unalterable rule, but should be given a more flexible treatment. The two adverse factors, gain in clearness and loss of time, must be balanced one against the other in guiding the judgment as to a wise use of shade lines.

The light is regarded as coming from the upper left corner of the drawing in parallel rays, making an angle of 45° with the horizontal. A shade line is used to separate a surface which receives the light from one which does not. By sliding the 45° triangle along the T square and regarding the hypotenuse as a light ray, the surfaces receiving the light may be easily distinguished from those which do not. In general, the lower and right hand edges of all raised surfaces should be shade lines, while on depressed surfaces the shade lines are placed on the upper and left edges. The line of intersection between visible surfaces is not shaded, nor should dotted lines be shaded. A circle representing a hole is shaded as follows: Draw a 45° line through the center extending upward to the left. Set the com-

passes to the radius of the circle and place the needle point on the line just drawn and at a distance from the center of the circle equal to the desired maximum thickness of the shade line. Describe a semicircle which becomes tangent to the original circle on each side. A circle representing a raised surface is shaded in a similar manner except that the center for the semicircle is taken downward to the right.

Fig. 79 is an illustration of the use of shade lines.

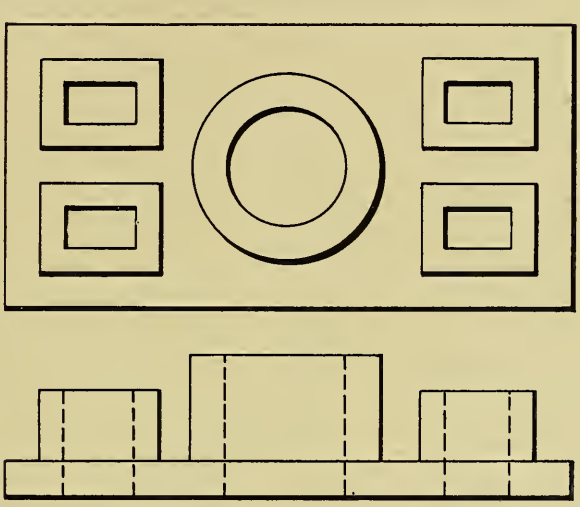


Fig. 79.—Shade lines.

63. Line Shading.—On display drawings or drawings intended for non-technical readers, it is highly desirable to represent more artistically and naturally the nature and relation of surfaces than is possible by the mere outline even though reinforced by shade lines. To gain a realistic effect surfaces in shade are distinguished from those in light by line shading. In general a surface is shaded by a series of parallel lines which decrease in weight as the lighter portion of the surface is approached. The gradual increase in width of the spaces between the line further increases the effect of the surface becoming lighter. Concave and convex surfaces are readily shown in this way.

The direction of the light is regarded to be such that the projections of the light rays make an angle of 45° with the horizontal. In Fig. 80 is shown the top and front views of a cylinder. If a plane of light rays be passed tangent to the cylinder the line of tangency is the darkest element. The brightest element will be the one from which the light is reflected directly to the eye of the observer. Since the angle of reflection of a light ray must equal the angle of incidence it becomes obvious by an inspection of Fig. 80 that the brightest element is found 22½° to the left of the center line.

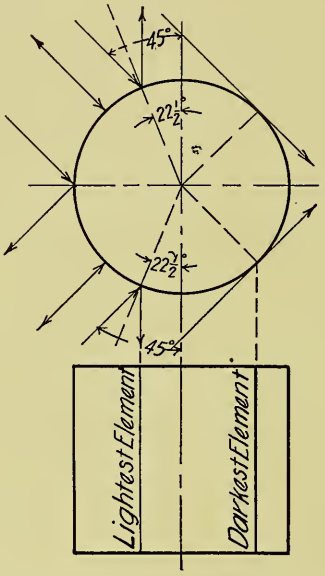


Fig. 80.—Position of light and dark elements of a cylindrical surface.

The cast iron pipe shown in Fig. 81 is shaded according to the method just discussed. Note that, beginning at the lowest side of the convex portion, the lines grow gradually heavier and closer together until the darkest element is reached, and then become gradually lighter in weight and further apart until the lightest element is attained. From the lightest element to the top of the cylinder the lines maintain the same weight but the width of spacing gradually decreases. In the concave portion of the pipe

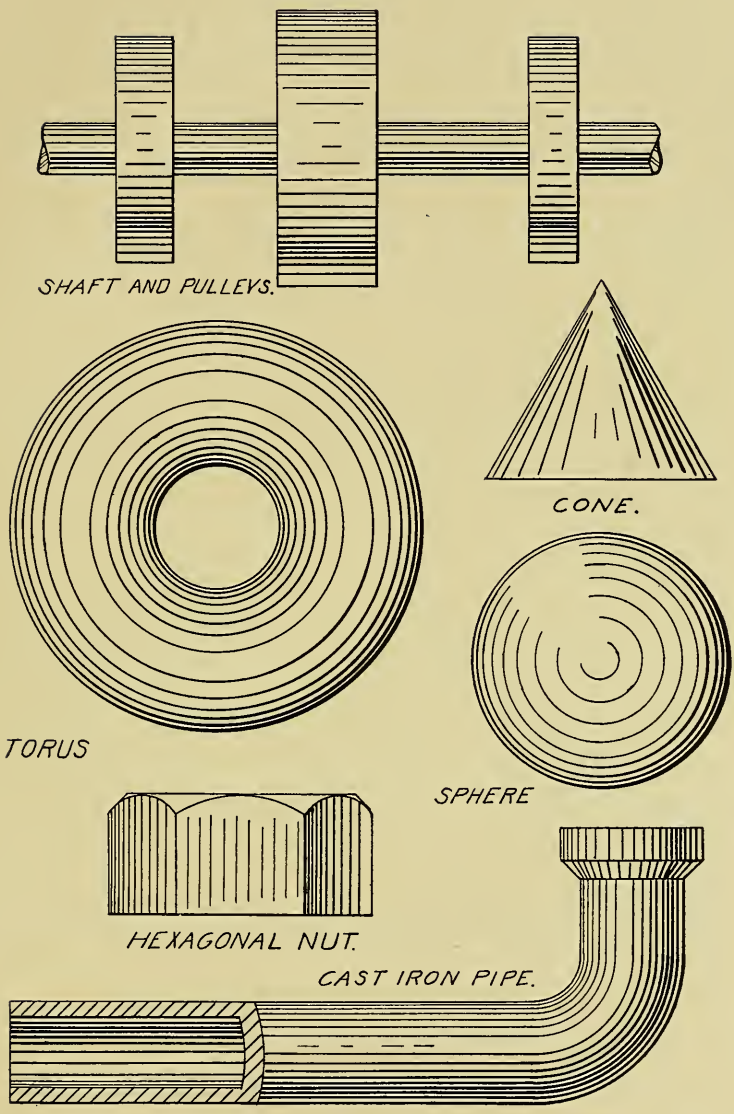


Fig. 81.—Line shading.

the lightest element is below the center line and the darkest element above. The methods used in shading the other objects of Fig. 81 are obvious. It is perhaps worth while to observe that, due to the closeness of the lines, it is almost impossible for the engraver to satisfactorily reproduce line shading. Hence the artistic effect which can be gained by line shading is not fairly represented in these illustrations.

The shading should progress from the bounding lines of the object inward toward the center, as it is easier to gradually increase the spacing than to decrease it. Center lines are not drawn in this class of work.

Line shading is required by the United States Government on all drawings submitted to the Patent Office.

64. Structural Drawing.—That portion of graphic language pertaining to the representation of all forms of steel construction, such as bridges, the skeleton framework for large buildings, etc., is called structural drawing. The steel used in the construction is rolled in various standard shapes and fastened together per-

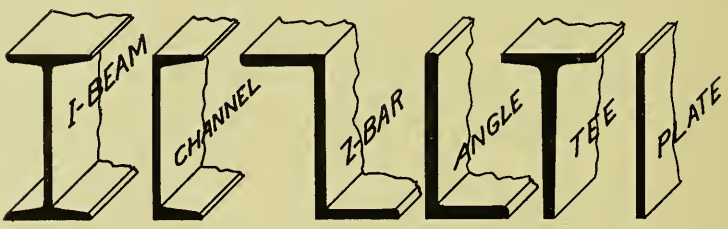


Fig. 82.—Rolled steel shapes.

manently with rivets. The purpose of this article is to point out certain idioms of expression used in structural drawing as well as to illustrate the principal shapes and forms of riveting used in steel construction.

The six most important shapes made in rolled steel are the I-beam, Channel, Z-bar, Angle, Tee, and Plate as illustrated in Fig. 82. In addition to these may be mentioned bars of various cross sections such as round, flat, and oval. These shapes are rolled in numerous standard sizes and are catalogued in the handbooks of the various steel companies.

The foregoing shapes are fastened together by rivets driven either by hand or machine, the latter being exclusively used

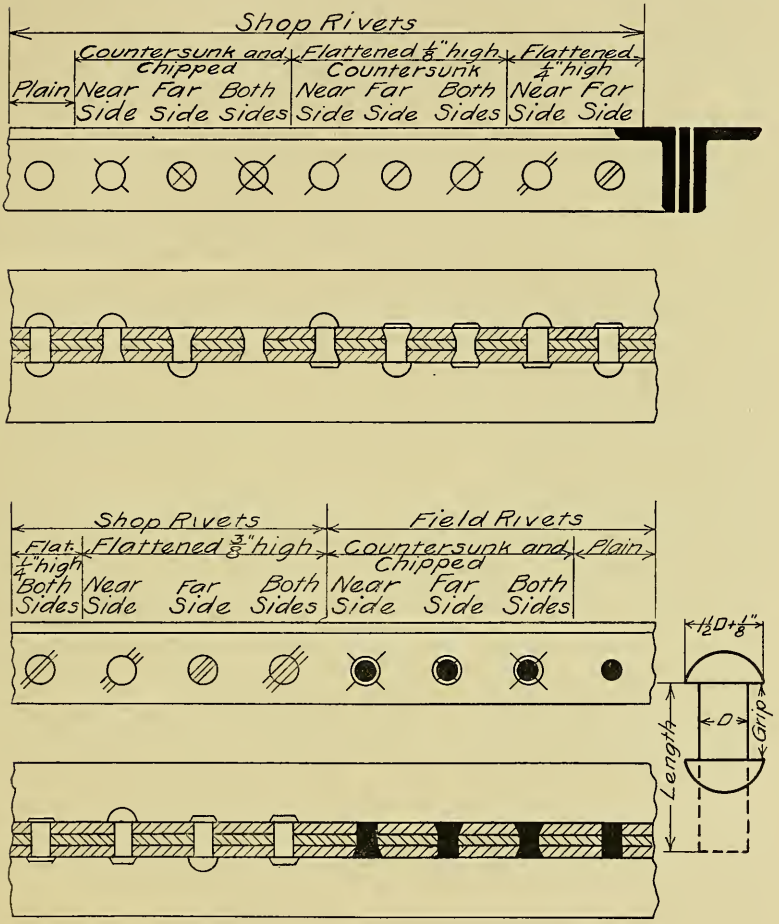


Fig. 83.—Standard representation of rivets.

wherever much riveting is to be done. All possible riveting is done at the shop, but a certain remainder must be driven in the field. One duty of the structural draftsman is to indicate which rivets are to be driven in the shop and which in the field. It must

also be shown whether the rivet heads are full, flattened, or countersunk. Fortunately there is a universally accepted standard for the representation of rivet heads. The symbols shown in Fig. 83 are so commonly known as to require no explanation when used on a drawing. Rivets vary in diameter from $\frac{3}{8}''$ to 1".

The method of showing a section in structural drawing differs from that to which the machine draftsman is accustomed. In Fig. 83 is shown an end section of the two angles and plate. Note that instead of cross hatching the cut material it is made solid black. The two angles are, of course, in actual contact with the plate, yet a hair line of white, or "streak of daylight" as it is sometimes called, is left between the pieces. This violates the letter of the law yet is justified by the increased clearness, for were the hair line of white omitted the section would become an unintelligible mass of black ink.

Dimension figures are placed just above the dimension lines. and dimensions over one foot are given in feet and inches, thus differing from machine drawing in both particulars.

The word "pitch" is used to indicate the distance from center to center of rivets which are equally spaced. Thus, if "3" pitch" be written just above a dimension line extending from one rivet to another, it is to be understood that all rivets included between the two extreme ones are 3" apart center to center.

The size of an angle is stated thus, $5'' \times 3\frac{1}{2}'' \times \frac{5}{16}''$ angle, the first two dimensions being the over-all lengths of the legs and the third representing the thickness of the material. The longer length is stated first.

In giving the size of a Z-bar, Channel, or I-beam, the over-all length of one leg, the distance back to back of the legs, the over-all length of the other leg, and the thickness of the material are stated in the order named, thus: $3\frac{1}{2}'' \times 6'' \times 3\frac{1}{2}'' \times \frac{3}{16}''$ Z-bar, $3\frac{1}{2}'' \times 10'' \times 3\frac{1}{2}'' \times \frac{1}{2}''$ Channel, or $4'' \times 3'' \times 4'' \times \frac{1}{4}''$ I-beam.

The size of a Tee is stated thus, $4'' \times 4'' \times \frac{1}{2}''$ Tee.

The length, width and thickness of a plate is given thus, $12'\text{-}0'' \times 8'' \times \frac{1}{2}''$ plate.

A Bill of Material must always accompany a structural drawing, either on the drawing, or separately.

CHAPTER VII.

Bolts and Screw Threads.

65. Since bolts and screws are the commonest forms of fastenings for machines, it behooves the draftsman to have a working knowledge of their formation. Fortunately the important dimensions are fixed by the United States Government and are regarded as standard. The purpose of this chapter is to indicate the conventional representation of bolt heads and nuts and screw threads.

66. The Helix is generated by a point moving around a given straight line and at the same time in a direction parallel to the

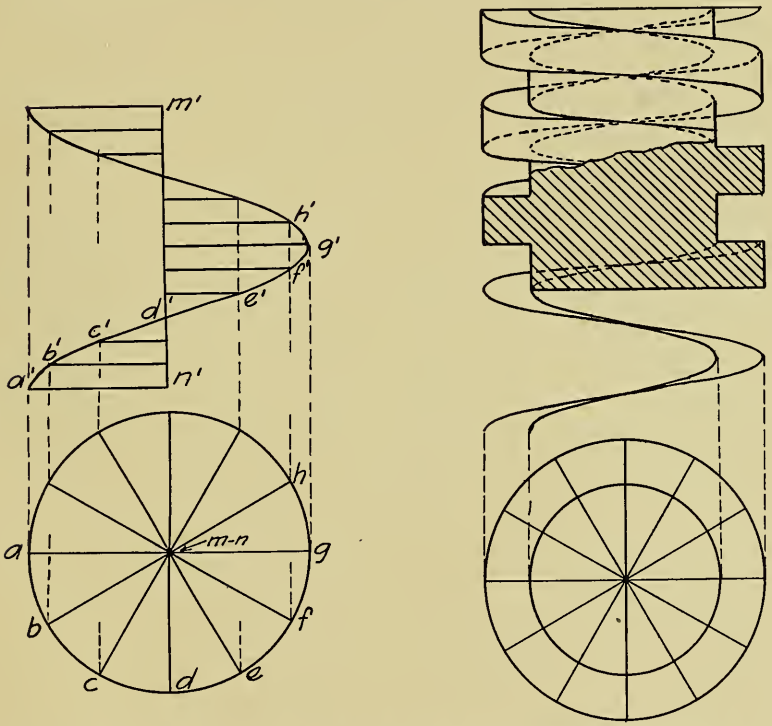


Fig. 84.—Construction of Helix, and application to square screw threads.

straight line, the two motions being uniform. The curve of a screw thread is the helix.

To construct a helix: In Fig. 84 let the circle adgj be the horizontal projection of the circular path of the generating point and let the line m′n′ — mn be the given straight line. Divide the circle and the straight line into any number of equal parts, in this case twelve. Consider the initial position of the generating point to be at a. As the point moves from a to b on the circle it must ascend $^1/_{12}$ of the length of the line m′n′; similarly when the generating point has reached d on the circle it must have ascended ¼ of the length of m′n′. Therefore from a, b, c, etc., erect perpendicular lines to meet horizontal lines drawn from the corresponding points of division on m′n′. The corresponding vertical and horizontal lines meet in points on the desired helix. The pitch is the distance the generating point moves along the line while making one complete revolution around it.

67. Various Forms of Screw Threads are in use which may be roughly divided into two classes, V threads and square threads. In general the V threads are used solely as fastenings and the square thread used to transmit power. In Fig. 85 are shown

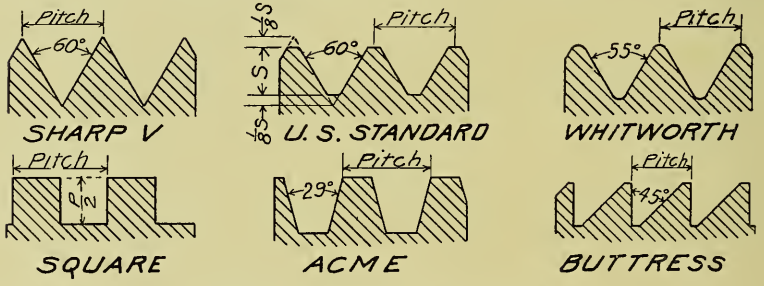


Fig. 85.—Standard screw threads.

cross sections of various types of threads. The United States Standard thread is the one most commonly employed in this country, while the Whitworth thread is the English Standard.

The standard proportions adopted in this country are as follows:

Let P = pitch, D = outside diameter and N = number of threads per inch; then

$$P = \frac{1}{N} = 0.24\sqrt{D + 0.625} - 0.175.$$

It will be observed, then, that the determination of either P, N or D immediately fixes the values of the other two. Thus, if the pitch desired is ⅛", N must equal 8 and the value of D may be deduced from the formula or by reference to one of the common tables of screw thread proportions.

A double screw thread consists of two threads, side by side, wound around the cylindrical core.

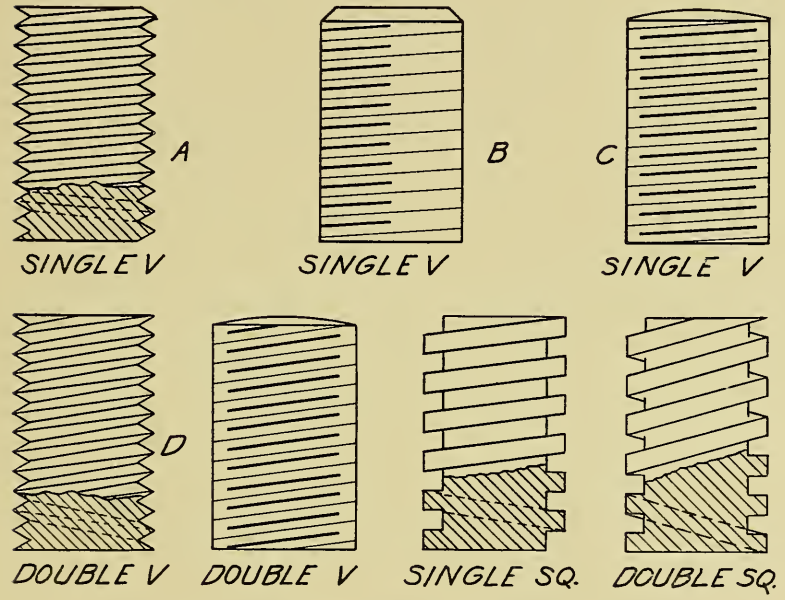


Fig. 86.—Conventional representations of screw threads.

Threads may be either right hand or left hand; the former advance away from the body when turned clockwise and the reverse is true for the latter. A left hand thread should be plainly marked on the drawing with the abbreviation L. H.

68. Conventional Representation.—It would be an absurd waste of time to show all screw threads as helixes. In Fig. 86 are shown several conventions for the representation of threads. The most frequently used conventions for single V threads are those given at B and C. The spacing of the lines is done solely by the

eye and the root lines are made heavier for effect. It is not necessary to actually draw the correct number of threads per inch. If the thread is standard mark it so and give the outside diameter. The threads shown in Fig. 86 are all right hand; left hand threads would slant in the opposite direction.

Some of the threads in Fig. 86 are shown partly in section merely to illustrate the construction. Note that the inner threads are not parallel to the outside threads—shown at A and D—but in the conventional representation shown at B and C all thread lines are made parallel for ease in drawing.

Two tapped holes are shown in Fig. 87, one in section and the other in elevation. Note that both of these holes are to receive

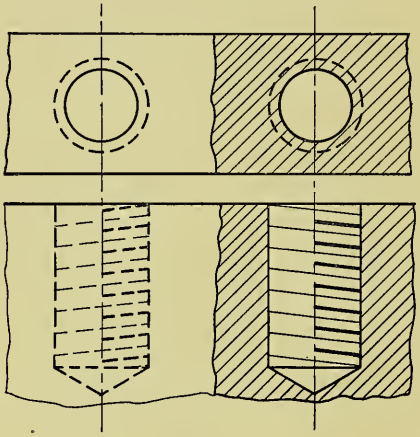


Fig. 87.—Tapped holes, in elevation and section.

right hand threads, hence the thread lines in the sectional view must slant in the opposite direction.

69. Bolt Heads and Nuts are generally square or hexagonal, and may be either chamfered or rounded. The chamfered nuts and heads are used on general work where nicety of finish is not desired, while the rounded forms are used on finished machinery where beauty as well as utility is a factor.

Three dimensions, pertaining to heads and nuts, have been fixed by the Government as standard: (1) the short diameter

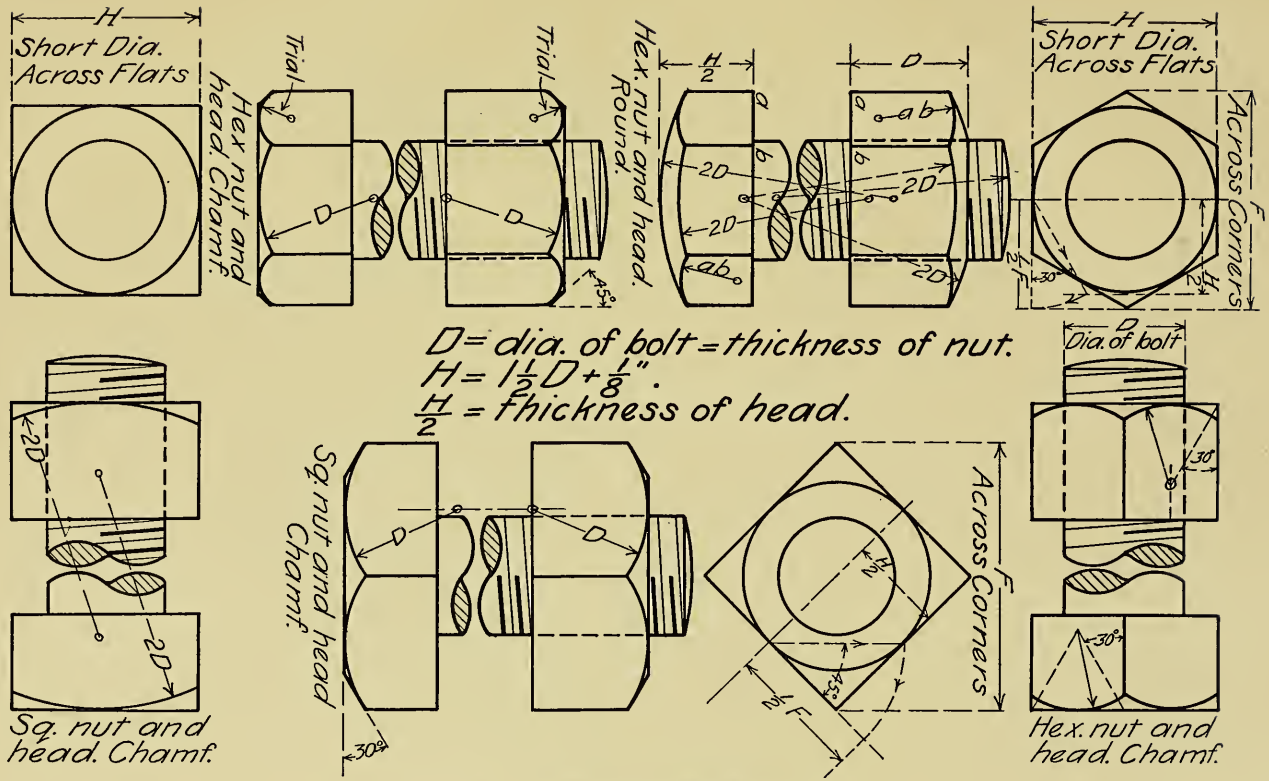


Fig. 88.—Standard bolt heads and nuts.

or distance across flats, (2) the thickness of the nut, (3) the thickness of the head. In Fig. 88 are shown various forms of hexagonal and square nuts and heads, whose construction is obvious from an examination of the figures. It is not necessary to draw a plan of a head or nut merely to ascertain the value of F, the distance across corners, since this distance can be obtained by the geometrical operation shown in both figures. It is, of course, evident that in elevation the two side faces of a hexagonal nut or head are each one-half as wide as the front face.

A nut or head should generally be drawn across corners, thus showing graphically the amount of clearance needed. Some drafting rooms even make it a fixed rule to require all nuts and heads to be drawn across corners in all views.

A standard nut or head is not dimensioned on a drawing but is marked "U. S. Standard" stating whether it is hexagonal or square and whether chamfered or rounded.

A lock nut is shown in Fig. 89. This nut is used on quick mov-

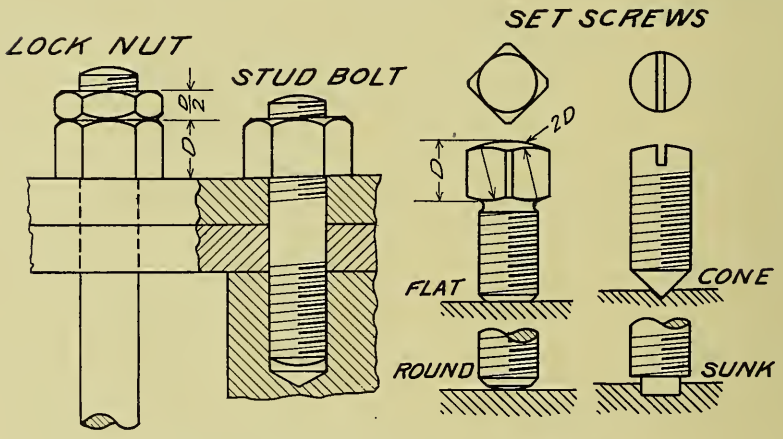


Fig. 89.—Lock nut, stud bolt, and set screws.

ing parts where a single nut could be easily loosened. Frequently both nuts are made equal in thickness, in which case the thickness of each is made equal to ¾ D, all the other dimensions being standard.

70. Set Screws.—The purpose of a set screw is to prevent the motion of one piece by pressing against another. In Fig. 89 are shown several forms of heads and ends.

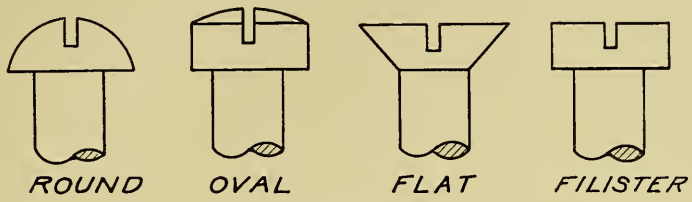


Fig. 90.—Machine screws.

The character of the ends is dependent upon the amount of resistance necessary. The resistance developed by the end of a

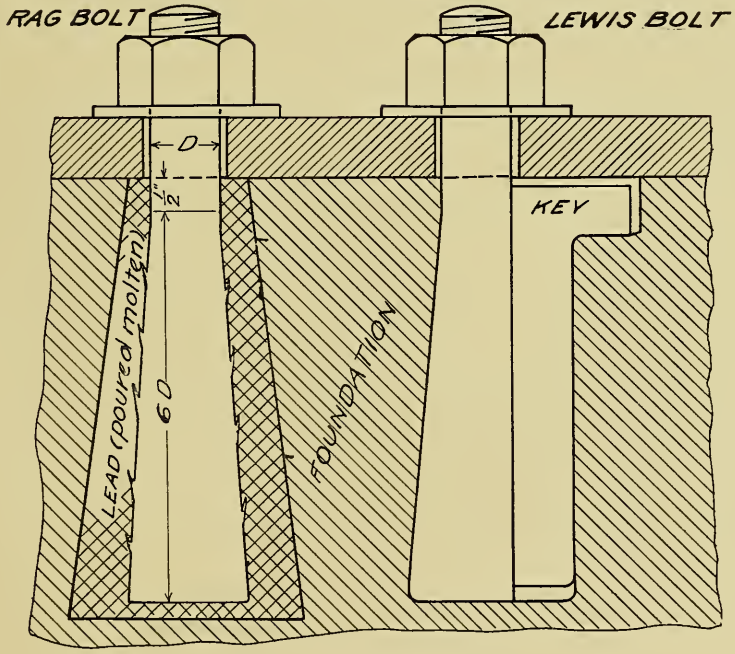


Fig. 91.—Foundation bolts.

set screw which protrudes into another piece is of course greater

than an end which depends upon friction alone, but with the disadvantage of requiring a cut in the piece touched.

71. A Stud Bolt is a screw, one end of which is to receive a nut and the other end to fit a tapped hole. In Fig. 89, note that in order to avoid confusion the threads of the tapped hole are not shown.

72. Machine Screws are used for fastenings. The four types of head in common usage are shown in Fig. 90. The dimensions for these screws may be obtained from any of the various machinists' hand-books.

73. Foundation Bolts are used for fastening heavy machinery to the foundation. There are various forms, two of which are shown in Fig. 91. The Rag bolt is inserted into a conical shaped hole which is then filled with molten lead, thus permanently fastening the bolt in place. In the case of the Lewis bolt the holding key can be withdrawn and the bolt removed.

CHAPTER VIII.

Tracings and Prints.

74. In general, the original pencil drawing does not leave the office but is kept on file for reference. The drawing is traced onto tracing cloth and from the tracing prints are made which are distributed as desired. The purpose of this chapter is to describe the details of this process.

75. Tracings.—Tracing cloth is a fine grained fabric treated with a preparation consisting principally of starch in order to render it transparent and fit to receive ink lines. One side is highly polished and glazed and the reverse side is dull. Either side may be used, but most draftsmen prefer the dull side since it takes the ink more readily and permits of pencilled detailing as well. On the other hand it is harder to erase an ink line from the dull side. If the smooth side is used it should be dusted with powdered chalk and then wiped clean. The red selvage edge should be removed and the tracing tacked tightly and smoothly over the drawing. This is best accomplished by first tacking diagonally opposite corners and then tacking the sides.

The pencil lines of the drawing are easily visible through the tracing cloth and the ink lines of the tracing are drawn immediately over the pencil lines of the drawing. The lines are inked in the same general order as given in Art. 22. It should, however, be borne in mind that tracing cloth contracts or expands according to the state of the atmosphere, and hence had best be inked in sections so that no unfinished section will be left from one day to another. The invariable tendency of the novice is to make the ink lines too light. In order to insure good printing, the lines of a tracing should be heavier than would be required on a drawing.

Dampness ruins tracing cloth and for this reason hands and bare arms should be kept off the cloth.

In general lettered notes or titles or cross hatching should not be traced, but should be placed on the tracing as though it were original work. A scrap paper copy can be made of the lettering

and a sheet of white paper slipped under the tracing and over the lettering of the drawing. Then proceed with the lettering of the tracing without reference to the drawing. Traced lettering seldom looks well, especially if traced by one who did not letter the original drawing.

Tracings may be cleaned by lightly rubbing with a cloth saturated with benzine or gasoline.

Pen wipers may be obtained by soaking scrap pieces of tracing cloth in water until the starch is thoroughly removed.

Tracing cloth is sold in 30″ to 54″ widths and in rolls from 10 to 24 yards long.

The tracing should never leave the office, the purpose of the tracing being to furnish prints as will be described in the next article.

76. Prints.—The most common form of print is the so-called blue print. Blue prints are made by laying the tracing face up on a sheet of specially prepared sensitized paper, clamping the two tightly together and exposing to the sunlight or strong artificial light. The light affects all of the sensitized paper except those parts covered by the ink lines of the tracing. The length of the exposure is dependent upon the degree of sensitiveness of the blue print paper and the strength of the light. The sensitized paper is then thoroughly washed in water and as a result white lines on a blue background are obtained. Such a print is called a blue print.

By using specially prepared papers the following kinds of prints can be obtained, Vandyke Negatives (white lines on a brown background), Blue Line Prints (blue lines on a white background), and Black Line Prints (black lines on a white background).

It is of interest to know that good prints can be made from typewritten matter provided a sheet of carbon paper was placed behind the page (carbon side next the paper) while doing the typewriting.

In the next article will be described several types of machines used in making prints.

77. Sun Frames.—In Fig. 92 is shown a sun frame mounted on a truck to run on rails outside a window so that it may be fully exposed to the sunlight. The tracing is laid face down against the glass in the frame, the sensitized paper is then placed against the tracing and covered by a piece of felt in order to uniformly distribute the pressure, and the whole clamped into position by the back of the frame. The truck is then run into the sunlight and the frame revolved about a horizontal axis until the glass surface is exposed to the light. Prints may be made on a cloudy day by giving a longer exposure. The length of exposure depends not only upon the sensitiveness of the paper but on the strength of the light, and for any given combination is best ascer-

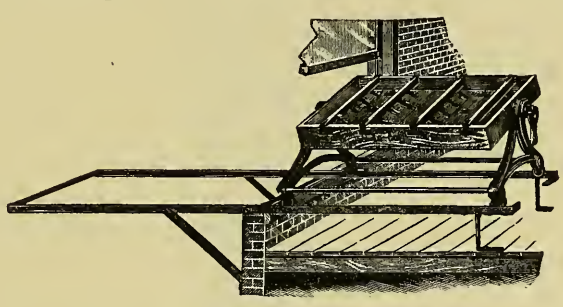


Fig. 92.—Sun frame.

tained by trial. Good prints cannot be made by this method on rainy days, and wherever much printing is done the sun method has been entirely supplanted by some form of electric printing machine as described in the next article.

78. Electric Printing Machines may be divided into two classes, those in which the paper and the tracing remain stationary during the time of the exposure and which may therefore be called the stationary type of blue printing machine. In the second type of machine the sensitized paper and the tracing are moved before a light in such a manner that successive prints are made on the sensitized paper. This machine is a continuous printing machine.

A Stationary Printing Machine of the vertical type is shown in Fig. 93. It consists essentially of a glass cylinder which is sup-

ported on end in a suitable frame. An arc light is arranged so that it may be moved up and down through the center of the cylinder, the speed of the movement being controlled by a pendulum or other device. To operate this machine the tracing or tracings, from which the print is to be made, is placed next to

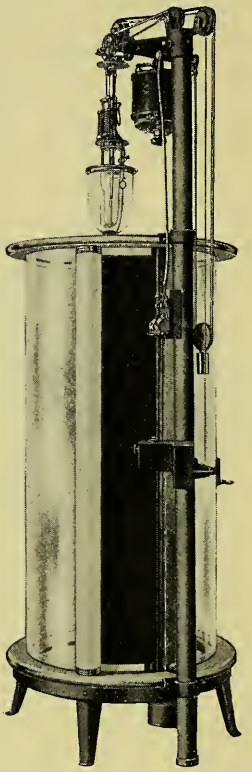


Fig. 93.—Buckeye Vertical Electric Printing Machine.—Sold by Technical Supply Co., Scranton, Pa.

the glass cylinder and the sensitized paper is held against the tracing by a curtain which is held tight by weights suitably arranged. The light having been raised, is then turned on and allowed to pass downward through the cylinder, the length of the speed regulating device having been so adjusted that one pass of the light will give the required length of exposure.

These machines are built in various sizes, any one of which will make a number of small prints or one large one at a time, one pass of the light making the exposure in either case. An exposure on this machine takes from one and one-half to three minutes, depending upon the sensitiveness of the paper and the condition of the tracing.

The Continuous Printing Machines are most successful when the surface on which the exposure is made is placed horizontally.

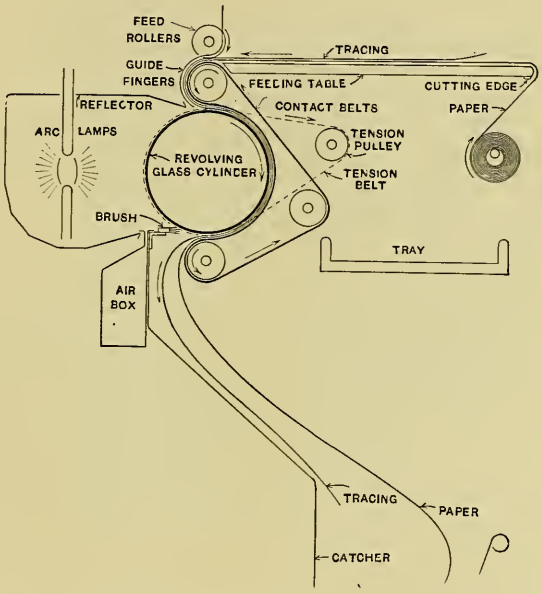


Fig. 94.—Diagrammatic view of Everett-McAdams Continuous Printing Machine.

They may be lighted by one or more arc lights or Cooper-Hewitt lights. The method of making the exposure differs somewhat, however, in different makes of the continuous printing machine. Fig. 94 is a diagrammatic end view of one of these machines. There is a glass cylinder which revolves around two Cooper-Hewitt lights placed near its center. The sensitized paper is passed around the cylinder to which it is held by the endless

belts. The tracings from which prints are to be made, are fed between the sensitized paper and the glass cylinder. It is obvious that the speed of this machine must be such that one revolution of the cylinder takes the time required to make an exposure.

A continuous printing machine that differs quite radically from the one just described is shown diagrammatically in Fig. 96.

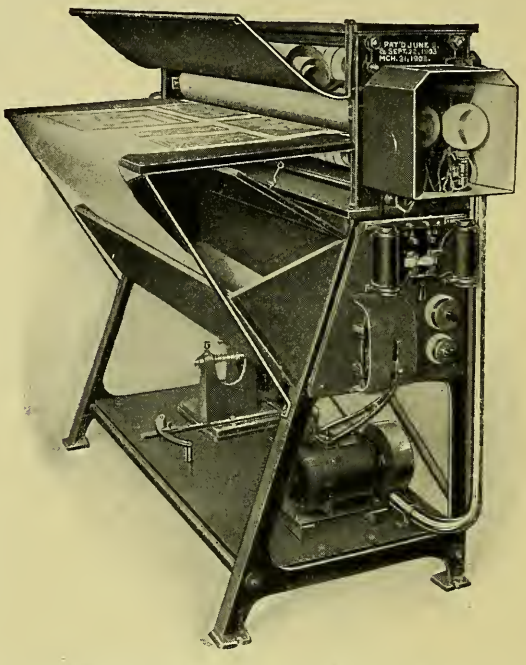


Fig. 95.—Everett-McAdams Continuous Printing Machine.—Sold by Technical Supply Co., Scranton, Pa.

This machine uses two, three, or four Cooper-Hewitt lights shown at a. The glass plates over which the tracings and paper are passed while making the exposure are portions of a cylinder having a long radius. These glass plates are placed close to the lamps so that the full intensity of the light is concentrated on the printing surface. The tracings and sensitized paper are held against the glass plates by tension belts, d, each of which is driven independently of the other. It is therefore possible to

make prints with two different kinds of sensitized paper at the same time even though the time of exposure may not be the same or, in case an extra long exposure is required, the print be passed first above the lights and then below them. This machine will

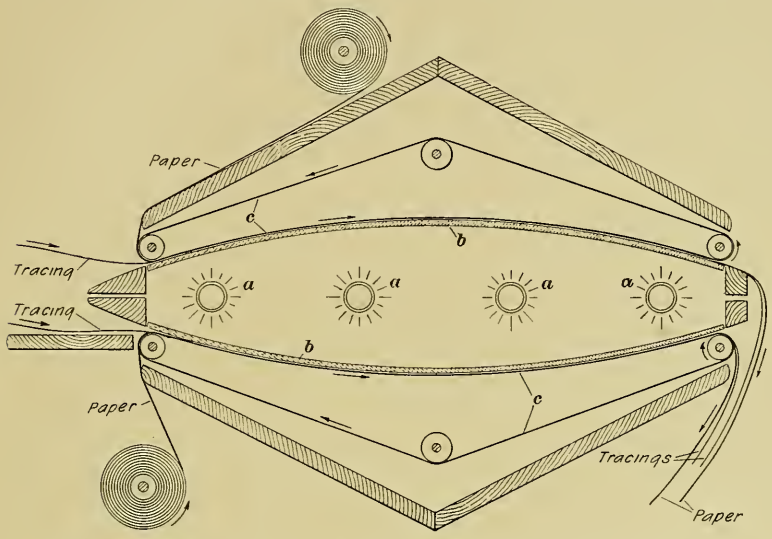


Fig. 96.—Diagrammatic view of Continuous Printing Machine.

print at the rate of from 1¼ to 12 feet per minute depending on the sensitiveness of the paper and the clearness of the tracing.

A print washing attachment may be combined with a continuous printing machine but, owing to the fact that it is difficult to wash a print thoroughly as fast as it can be exposed, this arrangement does not promise very good results.

APPENDIX.

SUGGESTED COURSE IN MECHANICAL DRAWING.

First Year Course in Drawing and Lettering.

79. Time Devoted to Course.—The course in drawing extends throughout the Freshman year. During the first, second and third terms there are two two-hour drawing exercises per week, and during the second and third terms there are two one-hour recitations per week. Twenty-two plates are completed in this course. The course in lettering covers the first term, in which there are two one-hour exercises per week. Fifteen plates are made during the course.

80. Roll Call.—A roll will be called immediately at the opening of each exercise, and a student arriving after this roll has been called will be marked tardy. Two such tardinesses, unless excused for special reasons by the instructor in charge, will be regarded as one absence, and reported as such. A second roll call will be taken five minutes before the close of each exercise, and any student who is not working at his own table at this time, will be regarded as having been absent the entire period.

No preparations for leaving the drafting room should be made until after the conclusion of the final roll call.

81. Stamping Plates.—As soon as the border lines of a plate are laid out in pencil, the student should ink his name, number, and plate number in their proper places. Before doing any further work on the plate see that an instructor stamps the plate with a form which states "Started....., Finished....., Instructor....." and places the date after the word "Started." When the plate is completed do not remove same from the board until an instructor has placed the date of completion after "Finished" and signed his initials after "Instructor."

82. Posting of Accepted Plates.—On the bulletin board will be found a form stating the names of the men taking each course and the number of plates in each course. Under each plate number is a date, which indicates the last day on which that particular plate will be accepted with full credit. A plate handed in less than two weeks after that date will be given half credit and

any plate more than two weeks overdue will be given a grade of zero in making up the final grade for the course. In this connection due allowance will be made for permitted absences.

A plate handed in during one exercise will be examined before the next exercise and if satisfactory an X will be placed opposite the name of the student and under the proper plate number.

83. Plates Returned for Correction.—Any plate which is not acceptable, but that can be made so, is returned to the student for correction. Attached to the plate is a correction sheet on which are noted the necessary corrections. These changes are to be at once incorporated in the drawing, and both drawing and correction sheet returned at once to the office. The immediate correction of a plate should take precedence over any other work upon which the student may be engaged.

84. Rejected Plates.—A plate will be rejected if the general character of its work is not up to the standard required by this department. The lower left hand corner of such a plate will be cut off and a correction sheet attached on which are noted the main reasons for the rejection of the plate. The rejected plate must be redrawn immediately after the completion of the plate upon which the student is then working, and the new plate handed in with the correction sheet attached.

85. Time of Posting and Returning Plates.—At the next exercise following the handing in of a plate, the student should determine from the list on the bulletin board whether or not the plate has been accepted. If the plate is not posted as accepted, it should be returned to the student, shortly after the opening of the exercise, as rejected or needing correction. If the plate is not accounted for in one of these ways, the matter should be called to the attention of the instructor in charge.

86. Conduct in Drafting Room.—The general deportment of the student in this drafting room will be governed by the same practical standards as effect the draftsman in professional drafting rooms. Brief conversation relative to the work in hand and carried on in a low tone of voice is permissible.

Necessary movement about the room such as for the purpose

of turning in a plate, consulting an instructor, examination of the model plates displayed on the bulletin board, is permissible.

Loud or unnecessary conversation, excessive movement about the room, or any manner of conduct which disturbs the others at work will not be tolerated.

The good draftsman works quietly and steadily. The student should do likewise.

Caps should be removed from the head before entering the room and not replaced until again outside.

Equipment should be unpacked and packed with speed and quietness.

87. Work Done Outside of Class Hours.—Under no condition is the drawing board to be removed from the drafting room. The student may work outside of the assigned class room hours, if he so desires, but such work must be done in the drafting room. Any work done on a plate outside of the drafting room, will be regarded as sufficient cause for rejecting the plate without further comment.

88. Bulletin Boards.—On the bulletin boards are displayed plates whose excellence render them worthy models. Or it may be that these plates indicate more clearly than do the plates in the text-book certain details in construction. Notices pertaining to the courses are frequently posted, for the knowledge of which the student will be held responsible. It is, then, highly desirable that the student should watch the bulletin boards carefully.

89. Size of Drawing Plates.—The over-all dimensions of the drawing plates are 12″ x 18″. A border line is drawn 1″ from the top and bottom edges, 1¾″ from the left hand edge and 1¼″ from the right hand edge, making the inside dimensions 10″ x 15″.

From the lower right corner of the border draw a light pencil line to the same corner of the cutting edge. Bisect this line, and with this point as a center describe a circle having a radius of $^{7}/_{16}$″. The circle should be drawn in ink, the width of line being somewhat heavier than a shade line. Draw in ink, but with a narrow line, a concentric circle just inside the outer circle leaving a hair space between the two circles. Draw lightly in pencil

the horizontal diameter of these circles and ¼" above this diameter another pencilled horizontal line. Between these two guide lines print in black numerals the number assigned the individual student at the opening of the course. Just under the center of the horizontal diameter print in letters $^3/_{16}$" high the course of study being pursued, using the following notation:

Civil Engineering	C. E.
Mechanical Engineering	M. E.
Electrical Engineering	E. E.
Mining Engineering	E. M.
Chemistry	C.
General Scientific	G. S.

For an illustration of the foregoing data see Fig. 97.

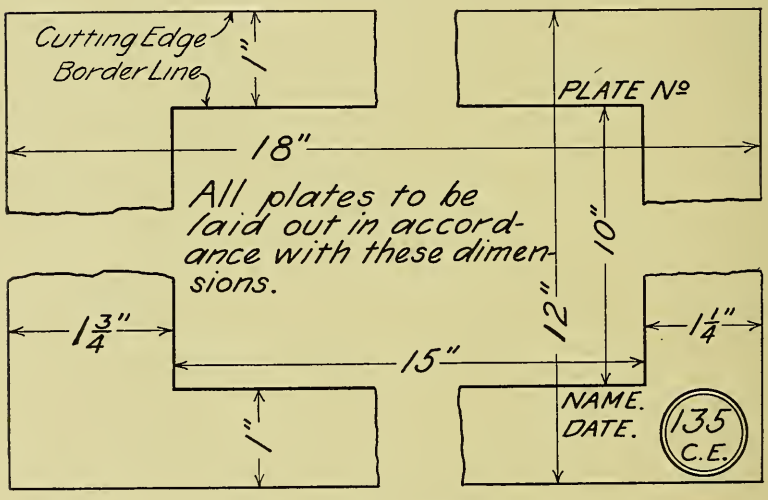


Fig. 97.—Layout of drawing plates.

90. Instructions Regarding Each Plate are given under the proper plate numbers. These instructions should be read and noted before starting the construction of each plate.

91. Binding Plates.—At the conclusion of each course the plates must be bound in bristol board covers, at a bindery approved by this department. The cost for binding the drawing plates is about thirty-five cents and for the lettering plates about twenty-five cents. Before credit will be given the students in either course the **bound** plates must be submitted to the instructor in charge.

Plates.

PLATE 1.

Before starting work on this plate, study articles 7, 9, 20 and 21.

The purpose of this plate is to afford practice in the use of the right line pen, and to illustrate the character of lines used in mechanical drawing.

Construct six 3¾″ squares leaving a space of ¾″ between each of the squares. The distance from the top border line to the top edges of the upper squares should be the same as the distance from the lower border line to the lowest edges of the under squares. Similarly the margin to the left of the squares should be equal to the margin at the right. It will be seen that the result of the foregoing work is two horizontal rows of squares, three squares in each row.

Divide the left hand edge of the first square in each row into thirty divisions of ⅛″ each. By means of the T square carry these points of division into each of the remaining squares. It will be noted that up to this point the work has been in pencil, whereas the following lines are ruled directly in ink without previously penciling them.

Through the points of divisions in each of the squares rule horizontal lines of the following character; in the first square, dimension lines; in the second square, visible outline lines; in the third square invisible outline lines; in the fourth square, center lines; in the fifth square, shade lines; and in the sixth square border lines which are one and one-half times as heavy as shade lines. (The squares are numbered horizontally from left to right.)

Ink the border lines of each square using the same weight line as is included in each particular square.

Under each square in lower case letters ⅛″ high state the name of the lines included in that square.

PLATE 2.

Before starting work on this plate study Article 11.

The purpose of this plate is to afford practice in the use of triangles and in the accurate drawing of radiating lines.

Set a point 4⅛″ from the left hand border line and 5″ below the top border line. With this point as a center describe two concentric circles having diameters of 5″ and ½″, respectively. Draw radial lines 15° apart terminating in these circles. Connect the ends of the radial lines by straight lines, thus forming a large and a small polygon of twenty-four sides. Divide the left hand, horizontal radial line into eight equal parts. Through these points of division construct eight more concentric polygons. Carry the lines half way around in each direction from the points of division, in order to reduce the closing error of the polygons to a minimum. Ink the polygons before inking the radial lines. Do not ink the circles as they were used for construction only.

Construct a 5″ square the right hand side of which is 1½″ from the right hand border line, and which is equidistant from top and bottom border lines. Divide the left and right sides into ten equal parts. From the division points of one side draw lines to the center point of the opposite side. Ink the radiating lines before inking the sides of the square. One line should be allowed to thoroughly dry before inking the next one to it. Use great care to make the intersections at the centers clean-cut and free from the blur of unnecessary ink.

PLATE 3.

Before starting work on this plate study Articles 3, 4 and 22.

The purpose of this plate is to afford practice in the joining of straight lines to circular arcs, as well as to familiarize the student with the use of both large and small dividers and compasses.

The layout and construction of this plate are indicated in the illustration at the right.

Wherever a straight line joins a circular arc, the arc should be first drawn and then the straight line drawn away from the arc. A smooth connection is essential to the good appearance of the work.

The centers of the circles inclosed in the equilateral triangle are found by trial with the dividers. Before inking one of these circles swing the pen of the compass around the path of the desired circle and just above the plane of the paper so as to ascertain if the circle will be exactly tangent at the proper points. If necessary, slightly shift the center and make a slight change in radius so as to obtain the desired result.

PLATE 4.

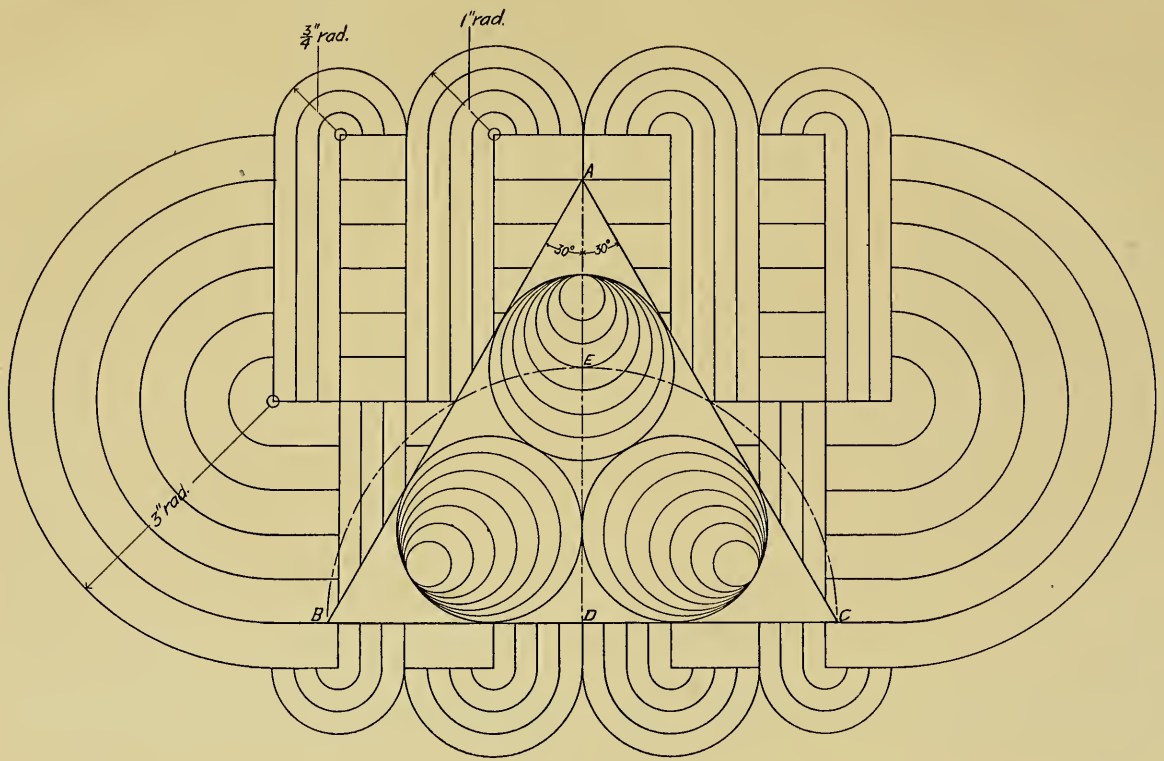
Before starting work on this plate study Article 23.

The purpose of this plate is to furnish practice in the drawing of lines of varying weights, and to illustrate symbolic cross hatching.

Construct two horizontal rows of 2″x2½″ rectangles, four rectangles in each row, the 2″ side of the rectangles being parallel to the long side of the plate. Allow a space of 1¼″ between each rectangle and a space of 1½″ between the two rows. The two rows are to be centered on the plate as regards the border lines.

In these rectangles represent the following materials, by symbolic cross hatching, in the order here stated; cast iron, wrought iron, cast steel, wrought steel, copper, brass, lead, and rubber. In each block state the name of the material represented using lower case letters 3-32″ high. Do not cross hatch over the lettering, but carry the lines as close to the letters as possible. All

PLATE 3



NAME
DATE

the section lines are to be drawn upward from left to right. Ink the section lines before inking the outline of the blocks. Shade the lower and right hand sides of each block.

The common fault of placing the lines of the cross hatching too close together should be avoided.

The section representing rubber (also vulcanite or any insulating material) is most easily made by ruling a series of heavy parallel lines in pairs, and filling in with ink the spaces between the adjacent pairs of lines.

PLATE 5.

The purpose of this plate is to afford an opportunity for gaining experience in the use of the free hand pen to illustrate various building materials. All lines on this plate are drawn free hand with the exception of the lines representing water.

The same relative size of the various materials should be, in general, the same as shown in the accompanying illustration.

The sand is composed of a great number of dots made with a free hand pen held almost vertically. Do not work too long at one spot as the ink of the individual blots will blur. Make a reasonable number of dots at one place, then move further along and return to the original place when the ink is dry. The dots should be very close together at the top and gradually become less towards the bottom.

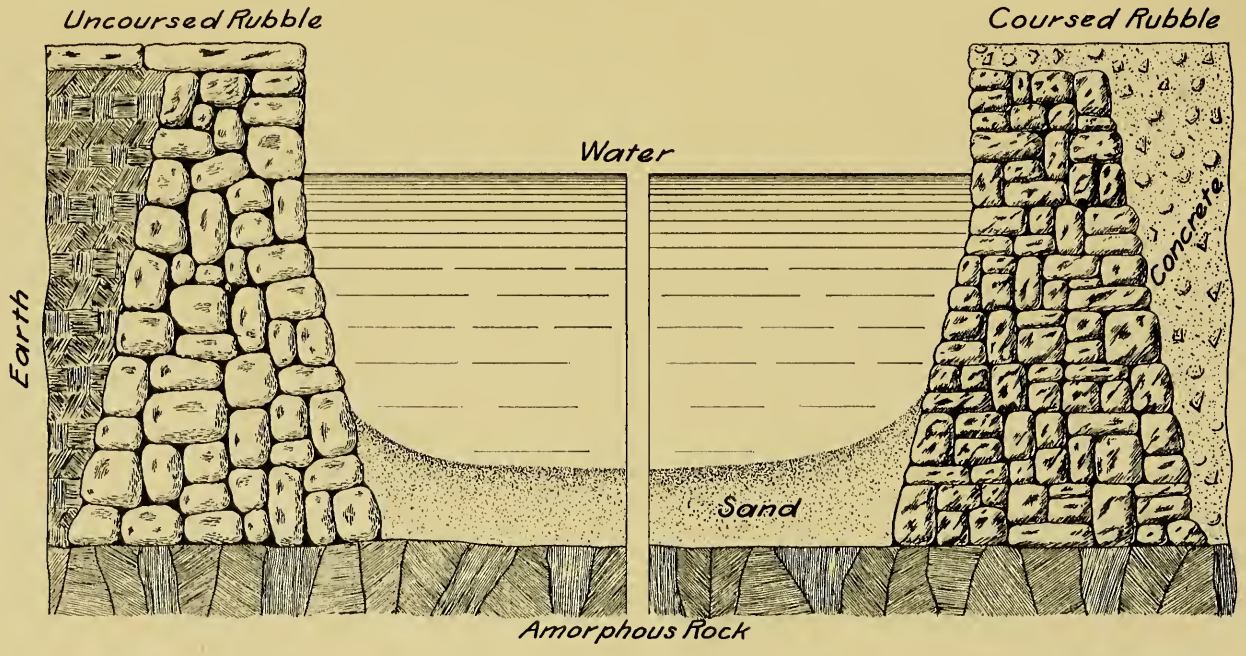
The concrete is composed of fine dots representing sand and cement through which are interspersed a number of small stones. Note that the stones are indicated by a shade line around the lower and right hand edges, no line being drawn for the upper and left hand sides.

The uncoursed rubble is masonry composed of rough stones which have been rudely dressed by knocking off angular corners. The stones are not laid in courses.

The coursed rubble is brought to a horizontal course line every few feet. Care should be taken, in representing masonry of any character, not to show too much mortar.

Earth and rock are represented by free hand parallel lines as shown; in the illustration these lines are too close together.

PLATE No 5



Name
Date

PLATE 6.

Before starting work on this plate study Articles 62 and 63.

The purpose of this plate is to afford practice in the use of shade lines and line shading.

The accompanying illustration consists of free hand sketches of various objects. These objects are to be accurately drawn to scale, though not necessarily in the same positions as here shown. Lay out all the pieces in pencil, before starting detail work on any piece, and submit the arrangement to an instructor for approval. After each piece is complete in pencil, apply the line shading and then ink the outline.

Do not show the hole in the top view of the bearing block as it would tend to destroy the effect of the shading.

State the name of each object but do not indicate the dimensions or scale.

PLATE 7.

Before starting work on this place study Articles 12, 33, 34, 35, 36, 37 and 38.

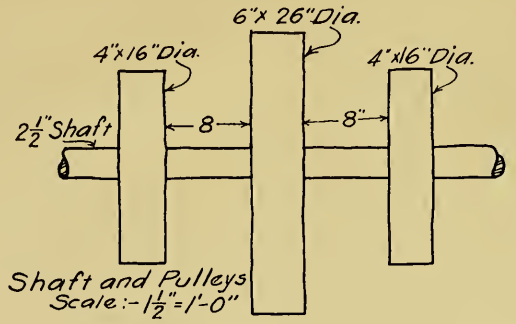
The purpose of this plate is to familiarize the student with the construction of the conic sections, as well as to afford practice in the use of the irregular curve.

The penciled layout of all the curves should be determined and submitted to an instructor for approval, before plotting the points of each curve.

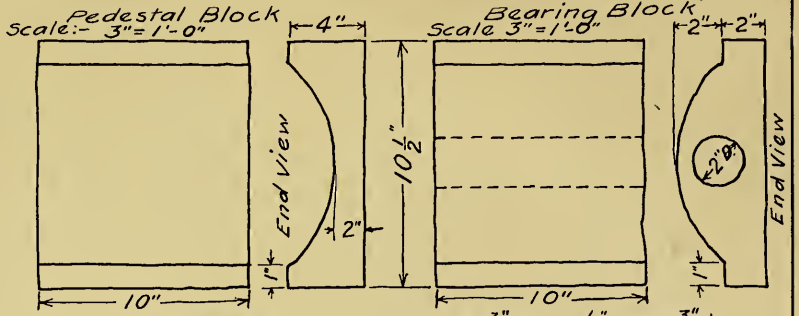
Construct an ellipse according to the second method of Article 36. Let the lengths of the major and minor axes be 4″ and 3″, respectively; use twenty-four radial lines spaced entirely by means of the triangles. The weight of the radial lines when inked should be the same as for dimension lines. The ellipse, as well as all other curves on this plate, should be the same weight as for a shade line. Draw a tangent to any point on the curve.

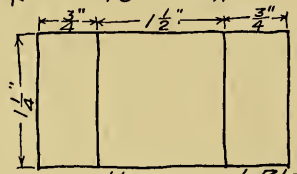
Construct an hyperbola, as explained in Article 38. Let $FF_1 = 2\frac{3}{4}''$ and $VV_1 = 2\frac{1}{4}''$. Plot a sufficient number of points to draw each branch of the curve with accuracy. Draw tangents from a point outside the curve and at a point on the

PLATE No 6

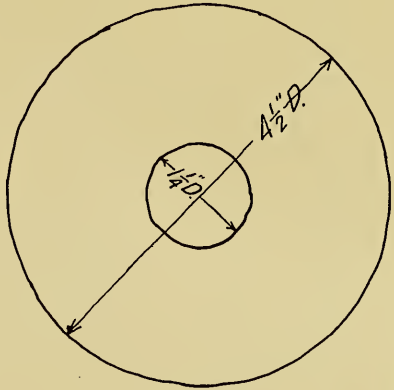


Shaft and Pulleys
Scale :- 1½" = 1'-0"

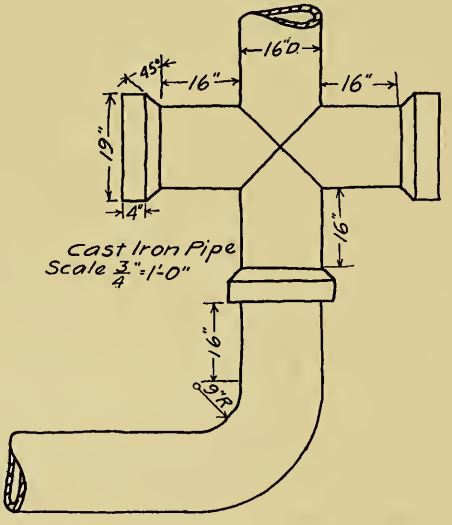




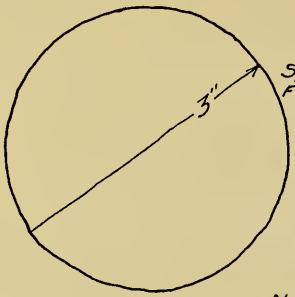
Hexagonal Block
Full Size.



Torus
Full Size



Cast Iron Pipe
Scale ¾" = 1'-0"



Sphere
Full Size

Name
Date

curve. Ink the construction lines used in obtaining one point only, on each of the branches of the curve.

Construct a parabola according to the second method of Article 37. Let the rectangle in which the parabola is enclosed be a 4″ square. Plot a sufficient number of points to draw the curve accurately.

Construct a parabola according to the first method of Article 37. Let F be distant ¾″ from the directrix. Let the last point chosen on the axis be 3½″ from the directrix. Draw tangents from a point outside the curve and also at a point on the curve.

In each of the foregoing constructions letter the axis, directrix, foci, and vertex. State the name of each curve in capitals ⅛″ high.

PLATES 8 and 9.

Orthographic Projection of Geometric Objects.

A thorough understanding of the chapter on orthographic projection is essential to the correct solutions of the problems on these plates.

Divide each of these plates into six 5″x5″ squares by light pencil lines.

Plates 8 and 9 each consist of six problems assigned by the instructor from the following list of problems as stated on page —: 1a, 1b, 1c, 2a, 2b, 2c, 3a, 3b, 3c, 4a, 4b, 4c, 5a, 5b, 5c, 6a, 6b, 6c, 7a, 7b, 7c, 8a, 8b, 8c, 9, 10a, 10b, 10c, 11a, 11b, 11c, 12a, 12b and 12c.

Completely solve each problem in pencil before starting the inking. Ink the outlines of the various views, but do not ink the ground line, profile plane trace, or the projecting lines. Erase the pencil lines used to divide the plate into six equal parts.

PLATES 10 and 11.

Revolution of Geometric Objects.

A thorough knowledge of the chapter on orthographic projection is essential to the correct solutions of the problems on these plates.

Divide each plate into four 5″x7½″ rectangles by light pencil lines.

Plates 11 and 12 each consist of one problem assigned by the instructor from the following list of problems as stated on page —: 25, 26, 27, 28, 29 and 30.

Complete each problem in pencil before starting the inking. Ink only the outlines of the various views.

PLATES 12 and 13.

Successive Revolution of Geometric Objects.

A thorough knowledge of the chapter on orthographic projection is essential to the correct solutions of the problems on these plates.

Divide each plate into four 5″x7½″ rectangles by light pencil lines.

Plates 12 and 13 each consist of one problem assigned by the instructor from the following list of problems as stated on page —: 31, 32, 33, 34, 35, 36, 37 and 38.

Complete each problem in pencil before starting the inking. Ink only the outlines of the various views.

PLATE 14.

Auxiliary Views.

A thorough knowledge of the chapter on orthographic projection is essential to the correct solutions of the problems on this plate.

Divide the plate into four 5″x7½″ rectangles by light pencil lines.

This plate consists of four problems assigned by the instructor from the following list of problems as stated on page —: 39a, 39b, 39c, 39d and 39e.

Complete each problem in pencil before starting the inking. Ink only the outlines of the various views.

PLATE 15.

Machine Details.

A thorough knowledge of the chapters on orthographic projection and working drawings is essential to the correct solutions of the problems on this plate.

Divide the plate into six 5″x5″ squares by light pencil lines.

This plate consists of six problems assigned by the instructor from the following list of problems as stated on page —: 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24.

In drawing these objects do not use the ground line or profile plane trace. If, in the opinion of the student, any view other than those called for in these problems will better illustrate the object in question, the student is at liberty to pencil the proposed view and submit same to an instructor for approval or condemnation.

Complete each problem in pencil before starting the inking.

PLATE 16.

Before starting work on this plate study Articles 66, 67, 68 and 69.

This plate consists of the following drawings of bolt heads and nuts, and screw threads:

Application of the helix to a single square thread of 1″ pitch and 3″ diameter similar to the one shown in Fig. 84. The thread is to be 3½″ long the lower part being shown in section. The thread is to be shown upright at the extreme left of the plate.

Rounded hexagonal head and nut, across corners.

Chamfered hexagonal head and nut, across flats.

Chamfered square head and nut, across corners.

Chamfered square head and nut across flats.

Two conventional representations—the style to be assigned by the instructor—of a single V thread, diameter 1⅜″, 6 threads per inch.

One conventional representation of a double V thread, diameter 1⅜″.

One conventional representation of a double square thread, pitch ½″.

Each thread is to be 3″ long.

The heads and nuts are to fit a bolt having a diameter of 1¼", 1½", or 1¾" as assigned by the instructor. In the case of a nut show the bolt broken on each side of the nut; for the head the bolt is shown on one side only.

The pencil layout of the various pieces, showing over all dimensions only, should be determined and submitted to an instructor for approval before detailing any view.

Draw threads directly in ink without previously pencilling them.

State the names of the various pieces in lower case letters $^{3}/_{16}$" high; also state the value of D, H, and $\frac{H}{2}$.

Dimension the heads and nuts in terms of D.

In the lower right hand corner of the plate state in capital letters $^{3}/_{16}$" high, "Standard Nuts, Heads and Screw Threads."

PLATE 17.

The accompanying illustration shows free hand sketches of various washers and fastenings. From these sketches the student is to make accurate working drawings.

In addition to the views shown in the illustration show a top view of the Cup and Ogee Washers, Separator, Boat Spike, and Drift Bolts.

Draw all pieces half size except the Dowel and Boat Spike which are to be drawn full size.

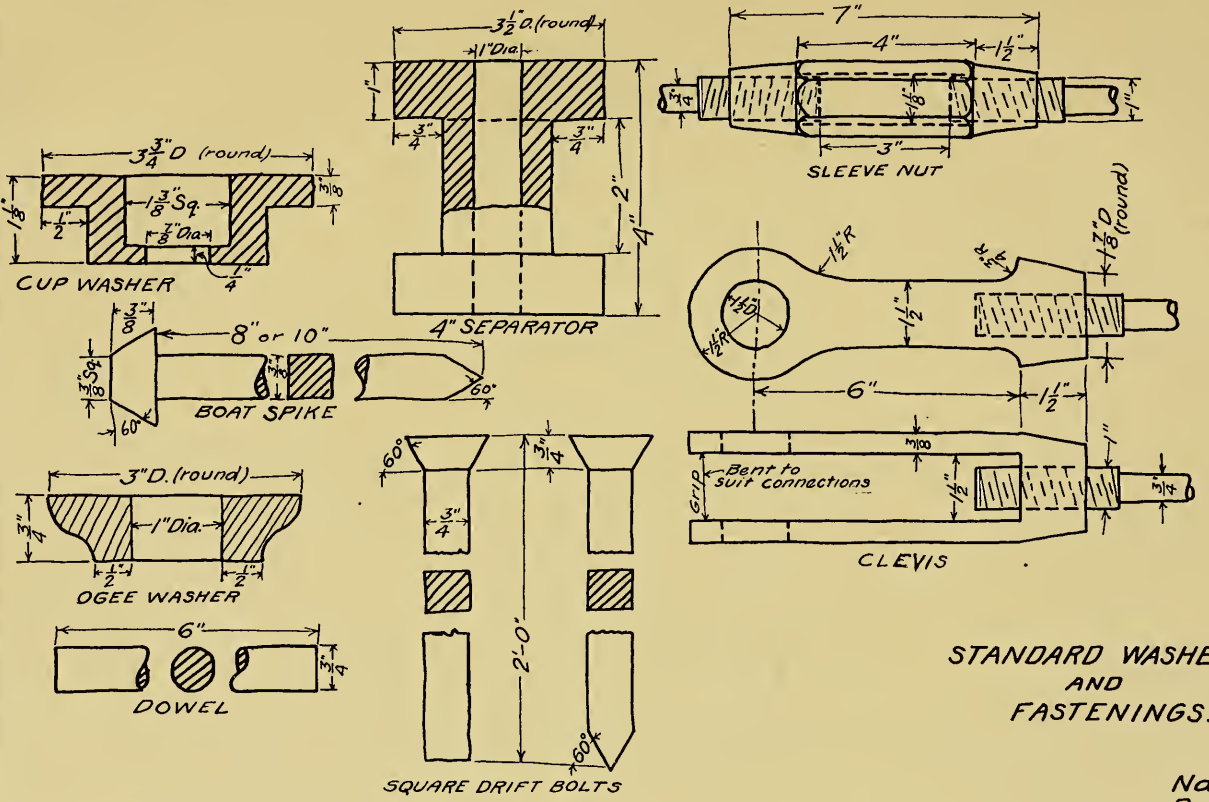
Lay out the over all dimensions of each view and submit the arrangement to an instructor for approval before detailing any view.

Use shade lines on all views, and represent convex or concave surfaces by line shading except in the case of screw threads.

In some of the sketches the word "round" is placed after a dimension representing the diameter of a circular piece. When the top view is shown the word is omitted.

Some of the fastenings shown on this plate are used in the construction of the timber trestle represented on the following plate.

PLATE No 17



STANDARD WASHERS AND FASTENINGS.

Name.
Date.

PLATE 18.

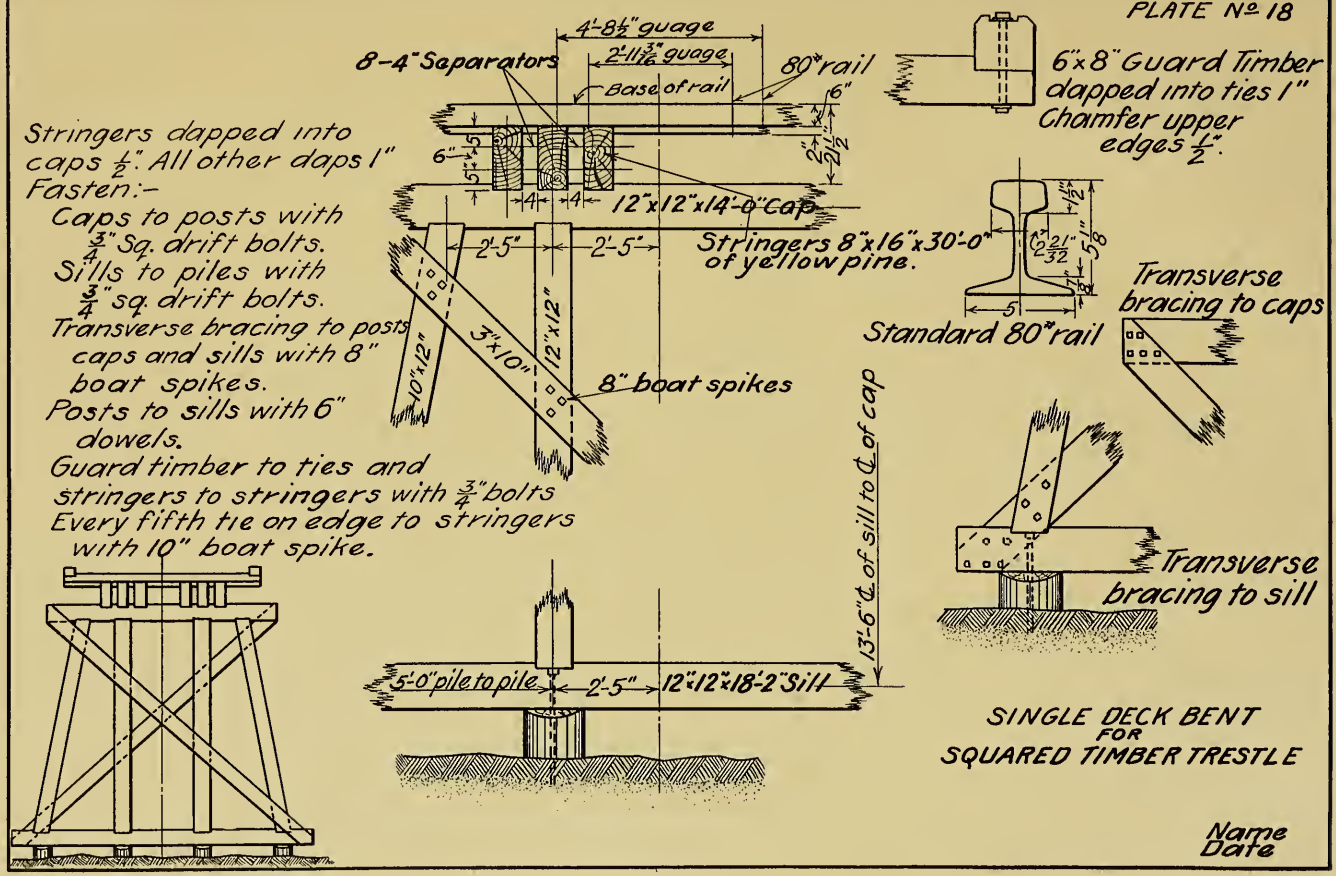
In the accompanying illustration are shown the details of a single deck bent for a squared timber trestle. From these details the student is to draw the complete bent to a scale of ½″ = 1′—0″.

The small drawing in the lower left hand corner shows the general form of the completed bent, and is not to be placed on the drawing made by the student.

Some of the fastenings enumerated in the note at the left are not shown in the details, but should be shown by the student as stated in the note. Some of the fastenings are shown in detail on Plate 17.

Use shade lines.

PLATE No 18



SINGLE DECK BENT
FOR
SQUARED TIMBER TRESTLE

Name
Date

PLATE 19.

The accompanying illustration is an **uncompleted** drawing of a squared timber highway bridge. From the data given the student is to make a complete drawing of this bridge to a scale of 1″ = 1′—0″.

Both the side and end views of all timbers are to be grained. The success of the graining is largely dependent upon the artistic ability of the student. Any arrangement of lines which gives a formal or mechanical appearance should be carefully avoided. Examine Fig. 31, obtain personal instruction, and devote a few minutes to practice before starting the graining. One result of the graining should be to make adjoining timbers stand out clearly.

After the drawing is completely inked and shade lined, apply the following light washes of color:

To all wood, "Light Wood."

To all iron work, "Prussian Blue."

To all masonry, "Prussian Blue," somewhat lighter than for iron.

To earth, one part of "Gamboge," two parts of "Light Wood," and a touch of India Ink.

To water, "Prussian Blue" dark at the surface and growing gradually lighter towards the bottom.

The common fault of the amateur to make all the colors too heavy should be avoided. Submit the washes to an instructor before applying.

PLATE No 19

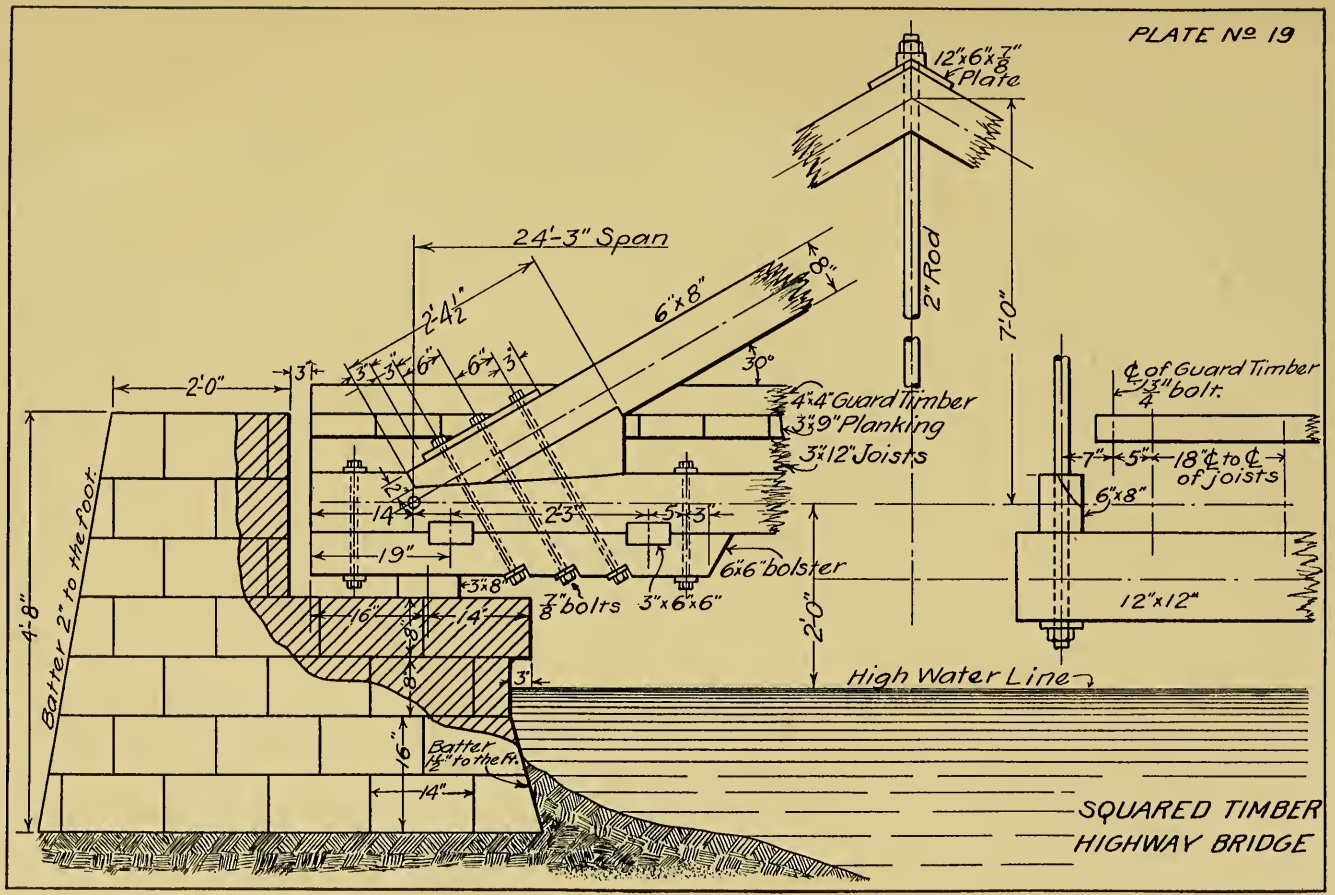

12"x6"x7/8" Plate
2" Rod
7'-0"
24'-3" Span
2'-4 1/2"
6"x8"
8"
30°
2'-0"
3"
3"
3"
6"
6"
3"
4"x4" Guard Timber
3"x9" Planking
3"x12" Joists
1 1/2"
14"
2'3"
5"
3"
19"
3"x8"
7/8" bolts
3"x6"x6"
6"x6" bolster
2'-0"
4'-8"
Batter 2" to the foot
16"
14"
3'-3"
3'
16"
Batter 1/2" to the ft.
14"
High Water Line
℄ of Guard Timber
3/4" bolt.
7"
5"
18" ℄ to ℄ of joists
6"x8"
12"x12"
SQUARED TIMBER
HIGHWAY BRIDGE

PLATE 20.

Before starting work on this plate study Article 64.

This plate consists of three drawings as follows:

Two views of the Z Bar column shown in Fig. 98.

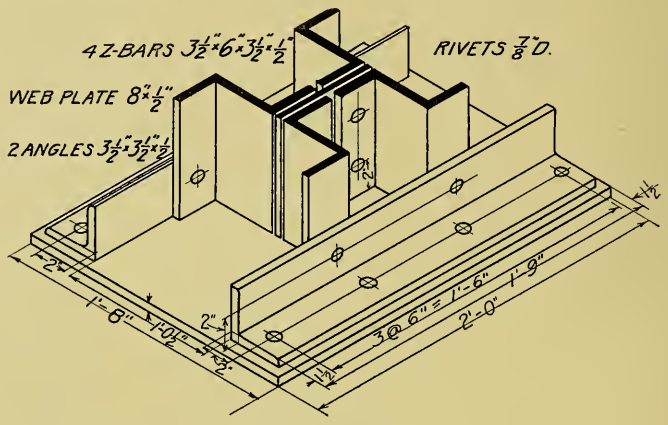


Fig. 98.—Z-Bar Column.

Two views of the Angle column whose cross section is shown in the accompanying illustration.

Two views of the Girder whose front view is shown in the accompanying illustration.

The scale in each case is to be 1½" = 1'—0".

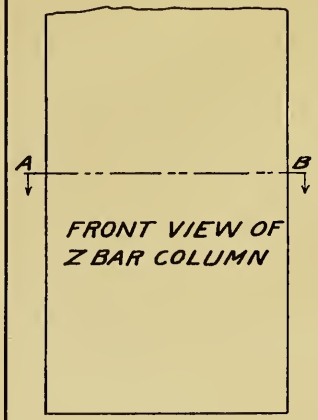
Layout the over all dimensions of the various views and submit the arrangement to an instructor before detailing any view.

Locate the center lines of the rivets in pencil, but draw the rivets directly in ink.

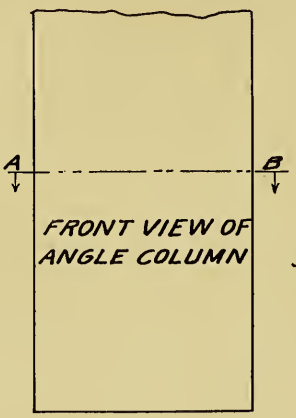
Do not use shade lines on this plate.

Diameter of all rivets $\frac{7}{8}$"

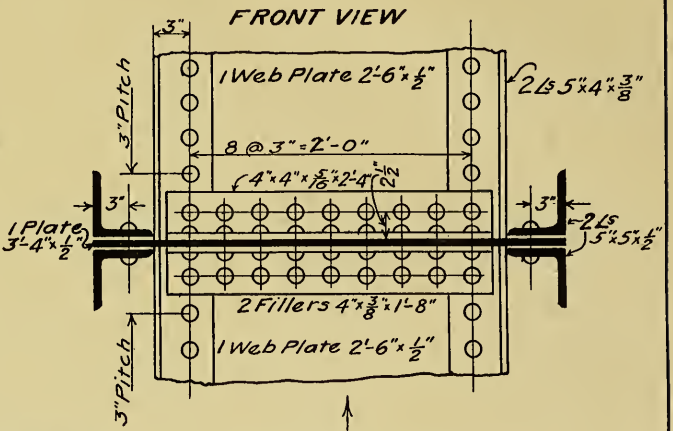
PLATE No 20



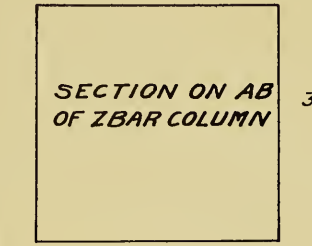
FRONT VIEW OF Z BAR COLUMN



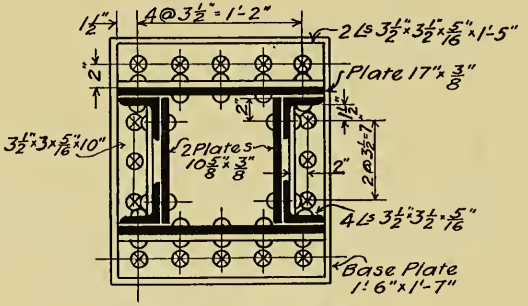
FRONT VIEW OF ANGLE COLUMN


FRONT VIEW
3"
3" Pitch
1 Web Plate 2'-6" x ½"
2 Ls 5" x 4" x ⅜"
8 @ 3" = 2'-0"
4" x 4" x 5/16" x 2'-4½"
3"
1 Plate 3'-4" x ½"
3"
2 Ls 5" x 5" x ½"
2 Fillers 4" x ⅜" x 1'-8"
1 Web Plate 2'-6" x ½"
3" Pitch

SHOW END VIEW HERE



SECTION ON AB OF ZBAR COLUMN



SECTION ON AB

BUILT UP COLUMNS AND GIRDER

Name
Date

PLATE 21.

Before starting work on this plate study Article 75.

This plate consists of a tracing made from one of the following plates as assigned by instructor: 6, 15, 16, 17, 18, 19 and 20.

PLATE 22.

Plate 22 is the title plate. The lettering consists of block letters similar to those shown on Plate VI of "Freehand Lettering"—Reinhardt, or similar to a model plate posted for this purpose by the instructor.

In capital letters $\frac{5}{8}$" high state "MECHANICAL DRAWING." Underneath and distant 1" state in capital letters $\frac{7}{16}$" high the name of the College. Below this line $\frac{7}{16}$" state in lower case letters $\frac{3}{16}$" high the name of the department in which the course was pursued, as "Department of Graphics;" the D and G in capitals $\frac{5}{16}$" high.

In the lower left hand corner of the plate in Reinhardt lower case letters $\frac{1}{8}$" high, state "Freshman Class 191- to 191-."

In the lower right hand corner state name, date and number as usual.

UNITED STATES STANDARDS FOR SCREW THREADS, NUTS, HEADS, AND WASHERS.

THREADS.			NUTS.						HEADS.		WASHERS.	
			HEXAGONAL			SQUARE			HEX. AND SQ.			
DIAM. (OUTSIDE)	THDS. PER INCH.	DIAM. AT ROOT	SHORT DIAM.	LONG DIAM.	THICKNESS.	SHORT DIAM.	LONG DIAM.	THICKNESS.	SHORT DIAM.	THICKNESS.	DIAMETER	THICKNESS.
1/4	20	.185	1/2	37/64	1/4	1/2	45/64	1/4	1/2	1/4	3/4	1/16
5/16	18	.240	19/32	11/16	5/16	19/32	53/64	5/16	19/32	19/64	7/8	1/16
3/8	16	.294	11/16	51/64	3/8	11/16	63/64	3/8	11/16	11/32	1	5/64
7/16	14	.344	25/32	58/64	7/16	25/32	1 7/64	7/16	25/32	25/64	1 1/4	5/64
1/2	13	.400	7/8	1	1/2	7/8	1 15/64	1/2	7/8	7/16	1 3/8	3/32
9/16	12	.454	31/32	1 1/8	9/16	31/32	1 23/64	9/16	31/32	31/64	1 1/2	3/32
5/8	11	.507	1 1/16	1 7/32	5/8	1 1/16	1 1/2	5/8	1 1/16	17/32	1 3/4	1/8
3/4	10	.620	1 1/4	1 7/16	3/4	1 1/4	1 49/64	3/4	1 1/4	5/8	2	1/8
7/8	9	.731	1 7/16	1 21/32	7/8	1 7/16	2 1/32	7/8	1 7/16	23/32	2 1/4	5/32
1	8	.837	1 5/8	1 7/8	1	1 5/8	2 19/64	1	1 5/8	13/16	2 1/2	5/32
1 1/8	7	.940	1 13/16	2 3/32	1 1/8	1 13/16	2 9/16	1 1/8	1 13/16	29/32	2 3/4	5/32
1 1/4	7	1.065	2	2 5/16	1 1/4	2	2 53/64	1 1/4	2	1	3	5/32
1 3/8	6	1.160	2 3/16	2 17/32	1 3/8	2 3/16	3 3/32	1 3/8	2 3/16	1 3/32	3 1/4	11/64
1 1/2	6	1.284	2 3/8	2 3/4	1 1/2	2 3/8	3 23/64	1 1/2	2 3/8	1 3/16	3 1/2	11/64
1 5/8	5 1/2	1.389	2 9/16	2 31/32	1 5/8	2 9/16	3 5/8	1 5/8	2 9/16	1 9/32	3 3/4	11/64
1 3/4	5	1.491	2 3/4	3 3/16	1 3/4	2 3/4	3 57/64	1 3/4	2 3/4	1 3/8	4	11/64
1 7/8	5	1.616	2 15/16	3 13/32	1 7/8	2 15/16	4 5/32	1 7/8	2 15/16	1 15/32	4 1/4	11/64
2	4 1/2	1.712	3 1/8	3 5/8	2	3 1/8	4 27/64	2	3 1/8	1 9/16	4 1/2	11/64
2 1/4	4 1/2	1.962	3 1/2	4 1/16	2 1/4	3 1/2	4 61/64	2 1/4	3 1/2	1 3/4		
2 1/2	4	2.176	3 7/8	4 1/2	2 1/2	3 7/8	5 31/64	2 1/2	3 7/8	1 15/16		
2 3/4	4	2.426	4 1/4	4 29/32	2 3/4	4 1/4	6	2 3/4	4 1/4	2 1/8		
3	3 1/2	2.629	4 5/8	5 3/8	3	4 5/8	6 17/32	3	4 5/8	2 5/16		
3 1/2	3 1/4	3.100	5 3/8	6 7/64	3 1/2	5 3/8	7 39/64	3 1/2	5 3/8	2 11/16		

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